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TR-93-NAS8-38981-042

FINAL REPORT

**MINIMUM HAMILTONIAN ASCENT TRAJECTORY
EVALUATION (MASTRE) PROGRAM (UPDATE TO
AUTOMATIC FLIGHT TRAJECTORY DESIGN,
PERFORMANCE PREDICTION, AND VEHICLE SIZING
FOR SUPPORT OF SHUTTLE AND SHUTTLE
DERIVED VEHICLES) USERS MANUAL**

**SUBCONTRACT NAS8-38981
TASKS 1, 2, 3, AND 4**

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PREPARED FOR:

**MARSHALL SPACE FLIGHT CENTER
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MARSHALL SPACE FLIGHT CENTER, AL 35812**

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ABSTRACT

This report is one of three reports detailing work performed by Dynetics, Inc., under contract to the Propulsion Laboratory of the Marshall Space Flight Center (NAS8-38981). Primary analysis was to provide a MASTRE Trajectory Code update to automate flight trajectory design, performance predictions, and vehicle sizing for support of shuttle and shuttle derived vehicles. Technical coordination was provided by Mr. Dan Adams and Mr. David Anderson of EP-56.

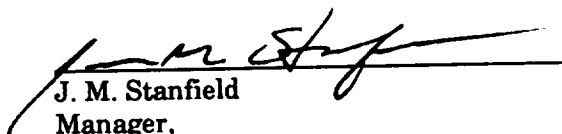


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1. INTRODUCTION

This report provides documentation for the User Interface Program for the Minimum Hamiltonian Ascent Trajectory Evaluation (MASTRE). The User Interface Program is a separate software package designed to ease the user input requirements when using the MASTRE Trajectory Program. This document supplements documentation on the MASTRE Program that consists of the MASTRE Engineering Manual and the MASTRE Programmers Guide. The User Interface Program provides a series of menus and tables using the VAX Screen Management Guideline (SMG) software. These menus and tables allow the user to modify the MASTRE Program input without the need for learning the various program dependent mnemonics. In addition, the User Interface Program allows the user to modify and/or review additional input Namelist and data files, to build and review command files, to formulate and calculate mass properties related data, and to have a plotting capability.

This document has been prepared to provide the user a step-by-step tutorial for implementing the User Interface Program. Following the introduction, two sections are used for general discussions of the use of the MASTRE Trajectory Program and the User Interface Program. Section 2 is a discussion of the terms, nomenclature, and general operating procedures used in the simulation of trajectory problems on the MASTRE Program.

Section 3 is a discussion of the User Interface Program. The User Interface Program consists of 15 sections based on the divisions provided in the main menu of the program. These divisions are launch and initial conditions, thrust event related data, stage related data, propulsion data, aerodynamic data, attitude data, mass properties, environmental data, constants, operational options, optimization data, output options, dispersions, command file creation/modification, and plotting, and are discussed in Sections 4 through 18. Although the discussion will be provided in a sequential fashion, the user is not limited in the manner that he wishes to modify and/or review data while using the software. Section 19 describes the output produced by the MASTRE Program.

Appendix A describes the use of the user interface portion of the Mass Properties Program. The Mass Properties Program is a separate program that can be used to calculate mass properties data (i.e., center of gravity (CG), propellant flowrate, and weight overboard) for a variety of motor types. These motor types include throttleable and nonthrottleable liquid engines, solid-rocket motors (SRMs), and hybrid motors. Using data from the Mass Properties Program, the MASTRE Program can calculate, in a dynamic fashion, the longitudinal, lateral, and normal components of the CG. The user has the option of either using the data from the Mass Properties Program or using tabular values of propellant weight versus longitudinal, lateral, and normal CG.

Appendix B describes the input and output requirements of the Root-Sum-Square (RSS) Program. This program was written as a post-processor to the MASTRE Program to provide dispersion analysis output. Output of the RSS Program is in the form of tabular output or files that can be used with graphic software programs (i.e., Cricket Graph) to provide plots of the user-defined data.

Because of the use of the SMG routines, the User Interface Program is limited to use only on the VAX computer system or systems having these routines. Therefore, portability of this software to another computer system is limited and would require a major effort to place the User Interface Program on a computer system that does not have these routines.

Due to their size, the MASTRE Program, the User Interface Program, and the Mass Properties Program have not been integrated into one program. The interface between these three programs is the input files generated for the MASTRE Program by the User Interface Program and the Mass Properties Program.

2. IMPLEMENTATION OF TRAJECTORY PROBLEMS ON THE MASTRE PROGRAM

The implementation of a trajectory problem on the MASTRE Program necessitates that the user understands the basic input mechanics and be aware of the various options. Through proper option selection, the MASTRE Program can be used to simulate an assortment of trajectory problems varying from simple point mass trajectories to complex atmospheric moment balanced trajectories. This flexibility stresses the importance of understanding the available options. This section contains a discussion of the terms, nomenclature, general operating procedures, and options and explains the method of setting up a trajectory problem.

2.1 THRUST EVENTS

The trajectory profile is simulated and setup in the MASTRE Program as a succession of up to 15 thrust events, one or more of which describes a physical stage (there can be up to 5 stages). A thrust event is a period of time characterized by a continuous thrust profile (constant, zero, or varying in a continuous fashion). The declaration of a thrust event is based on a change in thrust and/or flowrate or the manner in which thrust and/or flowrate is derived, a change in attitude philosophy, an instantaneous weight drop (or jettison), a stage change, or at any time desired by the user. Each thrust event is initiated at the termination of the previous thrust event except, of course, for the first event that initiates the trajectory.

A typical thrust event profile for a three-stage trajectory simulation is shown in **Figure 2-1**. In this example profile, the first stage consists of two thrust events, the second stage also has two thrust events, and the third stage has only one thrust event. This profile could exemplify the trajectory of a two-stage booster with a single upper stage. The times associated with the beginning (or ending) of the thrust events reflect major events in the trajectory simulation. A great deal of generality is gained by allowing many of the input values to be dependent on the thrust event index rather than time from lift-off since the duration times of the thrust events are used as optimization parameters and can change the time from lift-off history significantly.

Input associated with the thrust event describes the parameter characteristics within the thrust event time period. However, since some data are applicable to more than one thrust event, a distinction is made between data associated with the entire trajectory, stage related data, and thrust event related data. **Table 2-1** provides a breakdown of the input variables into these classifications.

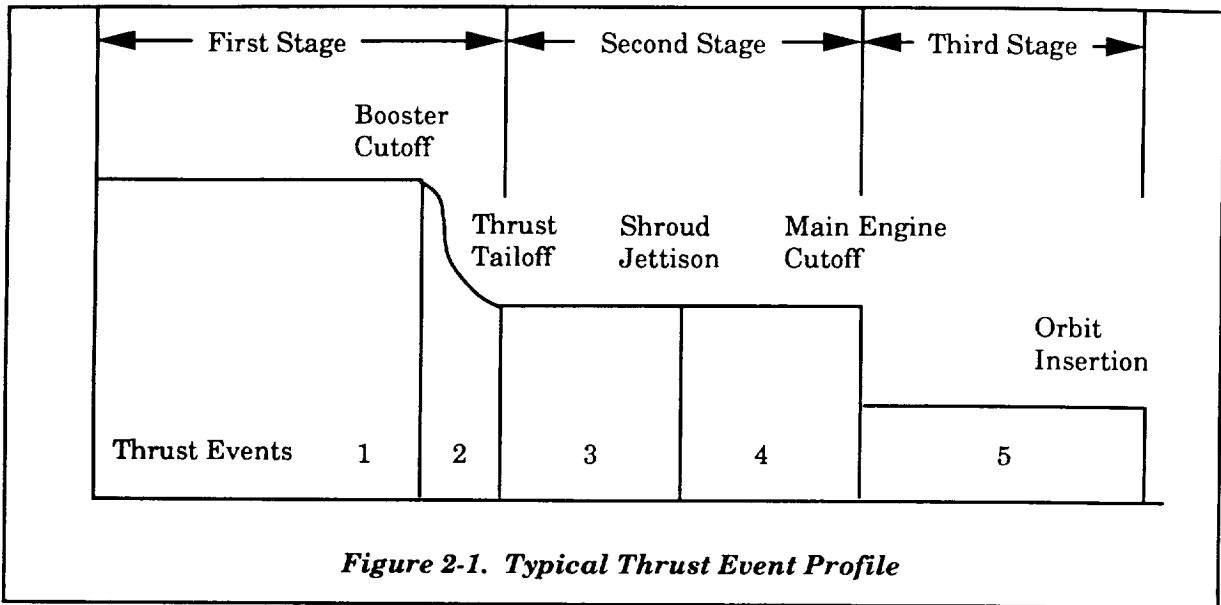


Table 2-1. Data Groupings

Entire Trajectory	Stage Related	Thrust Event Related
Liftoff weight	Aerodynamic coefficient tables	Vacuum thrust level
Flight azimuth	Base force tables	Propellant flowrate
Launch longitude	CG tables	Acceleration limits
Launch latitude	Aerodynamic reference length	Number and selection of engines
Engine data	Aerodynamic moment reference	Throttle options (MPS)
Wind tables	Attitude angle tables	Jettison weights
Optimization parameter selection	Attitude polynomial order	Drop weights
Terminal and intermediate constraint selection	Number of thrust events per stage	Time duration of event
Initial state requirements (if jump start)	Engine control option	Weight drop times
LBM data	SRB data	Number of weight drops
Initial time	MPS constant throttle levels	Integration stepsize (forward and backward)
Integration constants	AOA tables	Print interval
Output options	Vertical rise termination time	Aerodynamic reference area
Attitude control options	Roll maneuver initiation time	
Optimization scheme parameters	Tilt-over maneuver termination time	
Earth model constants	Branch trajectory parameters	

2.2 ATTITUDE CONTROL OPTIONS

One of the main purposes of the MASTRE Program is to define the optimum attitude of the space vehicle to maximize or minimize some payoff function while satisfying a variety of terminal and intermediate constraints. Optimization of the attitude is based on being able to express the partial derivatives of the equations of motion with respect to both the state variables and the attitude angles (in this case, the pitch and yaw angles). For some configurations like the Space Shuttle, the complexity of the booster stage nonlinear aerodynamic model prevents the application of the attitude optimization using the min-H strategy during the first stage. Therefore, additional attitude control options are available to use during portions of the trajectory when the min-H strategy cannot be used (of course, these options are not restricted to these portions and can be used whenever a particular attitude orientation is desired). The attitude profile after vertical rise for a vehicle that uses linear aerodynamics in the booster stage can be optimized using the min-H strategy. The following seven attitude control options are available:

1. Attitude control based on Mach number-dependent tables of angle of attack (AOA) and sideslip angle;
2. Attitude control based on time dependent nth-order polynomial equations;
3. Attitude control based on an alternate coordinate system (the Boost Reference Coordinate System) used by the Space Shuttle prime contractor; pitch and yaw angles are a function of Earth-fixed velocity, and the roll angle is a function of time from lift-off;
4. Attitude control based on Earth-fixed, velocity-dependent tables of pitch and yaw angles;
5. Attitude control based on time-dependent tables of pitch and yaw angles;
6. Attitude control based on maintaining a given value of the product of dynamic pressure and AOA ($Q\alpha$); and
7. Attitude control based on the min-H technique.

In all but Option 3, the roll angle is assumed to be in either a fixed heads-up or heads-down orientation.

Using Option 2, a quasi optimum attitude profile can be attained for either a portion or all of the booster trajectory (excluding the lift-off, or vertical rise, phase). Optimization requires the parametric variation of the angles used in the definition of the polynomial expression(s). Use of the other methods precludes optimization of the attitude history. Multiple options can be used within a given stage. For example, the polynomial attitude control can be used to simulate a tilt-over maneuver that can be followed by an attitude control based on AOA and sideslip angle. The implementation of

these options is further explained in Section 9. The following subsections describe the use of these options.

2.2.1 AOA/Sideslip Angle Control

AOA/sideslip angle control requires that the booster trajectory be subdivided into a minimum of three attitude phases:

1. A vertical rise phase where attitude is determined referenced to the Earth model;
2. A tilt-over maneuver consisting of attitude polynomials (in most cases a linear pitch function only) that are used to force the relative velocity into the desired flight plane-the amount of tilt-over angle required can be optimized by the variation of the angles used to define the polynomial(s); and
3. Continuation of the booster simulation based on the AOA/ sideslip angle history.

The first phase requires the input of the vertical rise termination time and requires no additional input. The second phase begins at the end of the vertical rise maneuver and ends at tilt-over termination time. Other inputs for this phase are described in Subsection 2.3. The third phase begins at the termination of the tilt-over maneuver and terminates at booster separation (the end of the stage). During this phase, AOA, sideslip angle, and Mach number tables are interpolated using input table values (see Section 8 for more details on the input requirements).

2.2.2 Attitude Polynomial Control

Two sets of attitude polynomials of the form:

$$c = a_0 + a_1 t + a_2 t^2 + \dots + a_n t^n \quad (2-1)$$

are available for a variety of uses. As discussed in the previous subsection, the tilt-over maneuver (phase 2) uses a polynomial expression, in most cases linear, to describe the attitude history during this maneuver. Input requirements for this maneuver are the tilt-over termination time, the order of the pitch and yaw polynomial expressions, values of pitch and yaw attitude angles that define the initial guess for the polynomial expressions, and table values of incremental time from the beginning of the tilt-over maneuver. Continuity of the attitude angles between the vertical rise maneuver and the tilt-over maneuver is maintained by internally setting the first values of the pitch and yaw attitude tables to the pitch and yaw values at the end of the vertical rise maneuver.

Optimization of the tilt-over maneuver polynomial expressions (except for the first values of the pitch and yaw tables) can be accomplished by setting the corresponding values of the parameter optimization indicator (see Section 13). For user convenience, the method of parameterizing the

attitude angles in the construction of the polynomial expressions is used rather than the polynomial coefficients.

2.2.3 Attitude Control Using the Booster Reference Coordinate System

Attitude control using the Booster Reference Coordinate System implies that pitch, yaw, and roll angles will be provided from lift-off to booster separation. The pitch and yaw angles (θ and ϕ) are input as tabular functions of Earth-fixed velocity, and the roll angle (σ) is input as a tabular function of time from lift-off. When using this option, neither the vertical rise maneuver nor the tilt-over maneuver are required. Also, no optimization parameters are available when using this option.

2.2.4 Attitude Control Using Pitch and Yaw Tables

This attitude control option has been placed in the program to allow the user to replicate the predefined booster attitude angles when performing a dispersion run. Using this option, the user can select the independent table for these angles as either time from lift-off or Earth-fixed velocity. Similar to the Booster Reference attitude option, the vertical rise and tilt-over maneuvers are not used for this option and, similarly, no optimization parameters are available when using this option.

2.2.5 Attitude Control Based on a Constant Value of Q-Alpha

This attitude control option has been included in the program to allow the user to maintain a given value of the product of dynamic pressure and AOA (or $Q\text{-}\alpha$). If the program is allowed to optimize the booster attitude profile, via min-H, it has been shown that the value of $Q\text{-}\alpha$ exceeds the design limits throughout most of the booster trajectory. By allowing the program to define the attitude based on the required limit of $Q\text{-}\alpha$, a constrained trajectory can be determined. Using this option is similar to the AOA option since the vertical rise and tilt-over maneuvers are required. The time of termination of the tilt-over maneuver should correspond to the time the $Q\text{-}\alpha$ approaches the constrained value (this time can be obtained by using the min-H strategy to optimize the booster trajectory). The termination of the $Q\text{-}\alpha$ can be accomplished by creating a thrust event that occurs when the $Q\text{-}\alpha$ on the optimum trajectory is less than the absolute value of the $Q\text{-}\alpha$ constraint value. At this thrust event, the min-H strategy may be initiated.

2.2.6 Attitude Control Using the Min-H Optimization Technique

The min-H optimization technique can be used to define the vehicle attitude any time following the vertical rise maneuver. However, as discussed earlier, the min-H technique can only be used when linear aerodynamics are used in the first stage. Otherwise, the min-H technique can be initiated at the beginning of the second stage (i.e., because of the nonlinear aerodynamics used in the

Space Shuttle simulation, the min-H technique can only be initiated after SRM separation). Initiation of this option is denoted by specifying the thrust event index that the min-H will begin. The attitude history during the min-H portion of the trajectory can be divided into seven independent phases of which phase is specified by an initiation and terminal thrust event index, the number of table points in each phase, and the tabular values of time and attitude angles. For each phase, the user can also select either in-plane (pitch plane only) or pitch and yaw control. The number of points in each attitude angle versus time table for each phase cannot exceed 29 points and must be an odd number of points (>1) due to the use of Simpson's Rule in the evaluation of the backward trajectory.

Although the user may require up to 29 points for a given segment, all 29 points in the attitude angle table array are not required as input. The reason is that the program, by linear interpolation, initially determines the attitude angles at discrete points on the trajectory regardless of the number of points input. After the initial iteration, however, the optimization algorithm continually alters both the independent and dependent tables and stores the required number of updated variables.

2.2.7 Post-Launch Roll Maneuver

When simulating the Space Shuttle, all of the attitude options, except for the Booster Reference option, can use a roll maneuver that simulates the post launch rotation of the vehicle so that the Orbiter tail fin is in the flight plane. This maneuver begins at the roll maneuver input time and ends at a time defined by dividing the angular requirement (the difference between the initial placement of the tail fin and the final placement based on a heads-up or heads-down orientation) and the input roll rate. If this maneuver is not required, the value of the roll rate should be set to zero.

2.3 INPUT REQUIREMENTS FOR THE EQUATIONS OF MOTION

Input for the MASTRE equations of motion require the user to provide aerodynamic, thrust, environment, and gravitational and Earth modeling data. The following subsections provide an overview of the input requirements for these models.

2.3.1 Aerodynamic Model Input

The modeling of the aerodynamic forces consists of two distinct models: nonlinear and linear. The nonlinear model is used for the Space Shuttle and consists of a series of equations that define the force and moment coefficients as a function of Mach number, AOA, sideslip angle, and inboard and outboard elevon deflection angles. The coefficients of these equations are expressed in a tabular fashion. Because of the large amount of data, the MASTRE Program uses an automated aerodynamic data base for the majority of the aerodynamic input data. This feature minimizes data handling by the

user and allows access to the latest aerodynamic data (which is maintained by the MSFC Aerodynamic Section). The capability to modify the nonlinear aerodynamic data has not been included in the User Interface Software since this data base is maintained externally.

The user can select to use either nonlinear and linear aerodynamic models or the linear model alone. Inputting the linear models requires providing tables of Mach number dependent values of constants and slope for the force and moment coefficients. Additionally, values of aerodynamic reference area, reference lengths, and axial and normal moment reference points are input as a function of stage.

The aerodynamic model also consists of base force data, elevon data, and hypersonic viscous interaction data. Base force data are input as altitude-dependent values of axial and normal force and pitching moment base force components. Separate tables of the base force data are available for the booster stage and the upper stages. Upper-stage data are also separated into engine-out and nominal data. Booster stage data require an additional table of reference dynamic pressure. AOA and sideslip angle dependent base force data, used for the Space Shuttle, are also available.

Elevon data, used for Space Shuttle simulations, are based on relative velocity and Mach number dependent tables of in-board and out-board deflection angles. Used in the nonlinear aerodynamics equations, the aerodynamic coefficients are based on the difference between the relative velocity dependent in-board and out-board deflection schedule and a Mach number dependent in-board and out-board deflection table.

Hypersonic viscous interaction data are based on the user providing tables of Mach number dependent constants, slopes, and accelerations (with respect to AOA) data for continuum flow and molecular flow of axial and normal force coefficients and pitching moment coefficients.

All of the above data, except for the nonlinear aerodynamic data, can be modified by using the User Interface Software.

2.3.2 Thrust Model Input

Six propulsion systems can be simulated in the MASTRE program. These systems are consistent with current or future NASA propulsion systems. Current systems are the Main Propulsion System (MPS), the SRM, the Orbital Maneuver System (OMS), and the Rocket Control System (RCS). The fifth system, the Liquid Booster Module (LBM), is available as a future liquid propulsion system. A sixth system, a fixed Main Propulsion System, is also available if the user wishes to simulate MPS engines that are not considered to be used in vehicle control (i.e., fixing an opposing engine in an engine-out situation).

An attempt has been made in the programming of these propulsion systems to generalize the input requirements, but, because of the uniqueness of each system, a totally general input was not practical. However, several input arrays do define, in a general nature, certain information concerning all propulsion systems. These arrays are denoted in the General Propulsion menu (see Section 6) as individual engine data, propellant per system, thrust event allocation per system, and thrust event allocation per engine. The individual engine data are defined by the following parameters:

1. Engine type (1-MPS, 2-SRM, 3-LBM, 4-OMS, 5-RCS, or 6-Fixed MPS);
2. Longitudinal location of engine i;
3. Vertical location of engine i;
4. Pitch cant angle of engine i;
5. Yaw cant angle of engine i;
6. Vacuum thrust of engine i at 100% power level;
7. Propellant flowrate of engine i at 100% power level; and
8. Nozzle exit area of engine i.

Propellant per system data provide the total amount of propellant weight per propulsion system. Propellant weight is used in several ways. Excess propellant is calculated in the weight summary tables based on differences between the total propellant weight and the amount of used propellants. Having individual weight arrays for each propulsion system allows for the integration and printout of the separate propellant weight time histories of each system. The propellant weight is also used when the user desires to terminate a stage on utilization of all consumable propellant.

Thrust event allocation per system data provide the number of system types to be used for each thrust event. Thrust event allocation per engine data specify the particular engine, based on the individual engine data index, that will be used for each thrust event.

Unique data for all propulsion systems are denoted in the User Interface Program by separate sets of data for each propulsion system. MPS data are subdivided into thrust event related data, throttle data, minimum throttle data, thrust tailoff data, and specific impulse data. Thrust event related data define the thrust option to be used during each thrust event. Six options are available: 1) normal operations, constant thrust and no throttling required; 2) throttle table used; 3) throttle table used but table is modified to achieve maximum dynamic pressure; 4) use variable throttle to maintain acceleration limit if limit is reached; 5) use constant throttle if acceleration limit is reached;

and 6) thrust tailoff. Throttle data, minimum throttle data, thrust tailoff data, and specific impulse data are input by time-dependent tables.

SRM, LBM, OMS, and RCS data are input by time dependent tables, which include thrust, flowrate, and, for the SRM, exit area.

2.3.3 Environment Model Input

Environmental modeling is based on a variety of atmospheric and wind models. Atmospheric models consist of a month dependent range reference model; the Patrick hot, cold, and reference models; and the Vandenburg hot, cold, and reference models. Wind models consist of mean annual winds, annual enveloping winds, monthly winds for both Eastern and Western Test Ranges, and wind tables provided by the user.

2.3.4 Gravitational and Earth Model Input

All gravitational and Earth model input is preset within the program. Gravitational and Earth model data are provided in the User Interface Program but are "read only" and, therefore, cannot be changed.

2.4 INTEGRATION SCHEME

The MASTRE Program can use one of three integration methods. These methods are an Adams-Moulton fourth-order scheme, which has the ability to select its own stepsize, a Runge-Kutta fixed step method, and a fixed step Adams-Moulton method. Different methods can be used for the forward and backward integration. Initial and fixed step sizes for forward and backward are input as a function of thrust event.

2.5 OPTIMIZATION METHODOLOGY

The flow logic of the MASTRE Program assumes that every problem simulated will determine the maximum, or minimum, of some payoff function subject to a set of terminal and intermediate constraints. Optimization is performed by the optimization of the attitude angles during the min-H phase and the optimization of certain trajectory parameters. The user can select a variety of constraints and parameters by proper input selection using the menus of the User Interface Program.

2.5.1 Selection of the Payoff Function and the Terminal and Intermediate Constraints

A large library of parameters can be used either as the payoff function, terminal constraints, or intermediate constraints (see *Table 2-2*). Menus (see Section 11) are used to allow the user to

specify which parameters, based on the library code index in *Table 2-2*, will be used as well as the constrained values.

Table 2-2. Payoff and Constraint Library

Library Number	Symbol	Function Name	Units
1	m_f	Cutoff weight	lb
2	V_i	Inertial velocity	m/s
3	γ_i	Inertial flight path angle	deg
4	R	Radius	m
5	h	Altitude above ellipsoid model	m
6	-	Not used	-
7	V_e	Earth referenced velocity	m/s
8	A_{ze}	Earth relative heading angle	deg
9	γ_e	Earth fixed flight path angle	deg
10	i	Inclination angle	deg
11	θ_n	Inertial descending node from launch	deg
12	-	Not used	-
13	-	Not used	-
14	ΔV	Orbital velocity including oblate effects (see Reference 7)	m/s
15	Q_{max}	Maximum dynamic pressure	lb/ft ²
16	H	Stagnation heating indicator	BTU
17	ΔV_{rtls}	Relative velocity increment from linear relationship between relative velocity and range (RTLS terminal condition)	m/s
18	ΔV_a	Velocity increment from linear relationship between ET propellant ΔV available and range (RTLS initiation condition)	m/s
19	R_{ng}	Range from the launch site	nm

2.5.2 Selection of the Control Parameters

In addition to the min-H optimization of the attitude control, several trajectory parameters can be optimized using the steepest ascent algorithm. The specification of these parameters is input by using the menu defined in Section 12. *Table 2-3* shows the parameters that are available to be optimized.

Table 2-3. Parameter Library

Library Number	Parameter Name	Symbol
1 to 15	Burn time for i^{th} thrust event	τ_i
16	Lift-off weight	W_{LO}
17	Launch azimuth	A_{zL}
18 to 24	Booster pitch attitude angles	χ_p
25 to 28	Booster yaw attitude angles	χ_y
29	Time to start MPS throttle ramp	t_a
30	Time after maximum dynamic pressure	t_e
31	Value of throttle at bottom of ramp	f
32 to 34	Values of sideslip angle history	β_i

2.6 SIMULATION OPTIONS

The following subsections discuss several simulation options available to the user.

2.6.1 Jump-Start Option

Reinitialization of the trajectory at a given time is handled differently depending on whether the "jump-start" time occurs during the first stage or during an upper stage.

The first-stage jump-start option operates by specifying jump-start times as input in a nominal trajectory. As additional input, an output file is requested by name if the first value of the jump-start time variables (see Subsection 13.5.2) has a non-zero value. If the demand mode is active, the user is prompted to define the file name; otherwise, the file is specified in the command file after the name of the Namelist file (see Section 17). During the converged trajectory, the state and other related parameters associated with the jump-start times are written to the named output file. The only constraint is that these jump-start times must occur within the first thrust event.

To run the jump-start trajectory, the output file generated in the above process is specified by the user in the same manner in either a demand or nondemand mode. The initial lift-off time parameter (see Section 4) specifies the time to begin the jump-start trajectory by comparing this time with the time parameters on the specified input file.

Reinitialization of an upper stage trajectory is designated by denoting, in the input, the thrust event where the jump-start will occur. Nominally, the assumption is that the trajectory will be initialized on the ground. In this case, the normal ground-to-insertion logic will be maintained. A ground-to-insertion trajectory requires the user to input the geodetic latitude, the longitude, and the

altitude of the launch site and the flight, or launch, azimuth. To initialize the upper-stage jump-start option, the user must supply the state parameters at the jump-start time, which is an array of 25 variables.

2.6.2 Branch Trajectory Option

The branch trajectory option allows the user to simulate both the nominal and engine-out trajectories within the same run. This capability allows the user to design the trajectory of the first stage based on meeting the terminal and intermediate constraints of both the nominal and engine-out trajectories. Input variables are used to save the branching point of the trajectory and indicate where the next portion of the trajectory begins.

The branch trajectory is setup in the same manner as other trajectories using thrust events and thrust event related data. The primary difference is that the trajectory is divided into stages, and the stages after the booster stage can be treated as separate trajectories. The terminal constraints are placed on the final stage, and the user must impose intermediate constraints on the remaining stages. Additional intermediate constraints can be handled in the same manner. Optimization is based on maximization of the sum of the final masses of the branching trajectories. Although time on the output is based on time from lift-off, the actual time within the simulation is a continuous function and consists of the summation of thrust event times.

For example, if an engine-out/nominal trajectory is being simulated, the trajectory should be divided into at least three stages: the booster phase, the engine-out phase, and the nominal phase. The user must provide the thrust event index, which begins the second stage, and a stage-dependent index, which indicates that the set of state variables stored will be used to initialize the third stage. If the second stage has two thrust events, for example 4 and 5, then the end point constraints will be considered intermediate constraints and will occur at thrust event number 5. The end conditions for the engine-out trajectory will be used to define the values of the intermediate constraints. These constraints are combined with the terminal constraints at the end of the nominal trajectory and any other intermediate constraints to define the total trajectory constraints. The user is limited to a maximum of 1 payoff function and 19 constraints (terminal plus intermediate). Another stage-dependent variable defines when the backward trajectory uses all data or partial data for attitude optimization. The value of this variable defines which set of intermediate constraint values are used with respect to the branch portion or, in this case, the second stage of the trajectory. For example, the attitude during the second stage will not be a function of the third stage optimization, but the first stage attitude optimization is a function of both second and third stages. Therefore, for this case, this variable will be equal to zero for the first stage, one for the second stage (since it relates to the first set of intermediate constraints), and zero for the third stage.

2.6.3 Dispersion Option

The MASTRE code generates an output file for dispersion analysis. This output file is utilized by a separate program (the RSS Program), which calculates the root-sum-square (rss) of various dispersions with respect to several nominal trajectory variables and displays the dispersion data via output tables and/or plot files (which can be used by graphical software). The specific parameters are shown in **Table 2-4**. Input parameters discussed in Section 16 are needed to exercise the dispersion option.

Table 2-4. MASTRE Output Variables for Dispersion Analysis

1. Time from lift-off (s)	14. Inertial azimuth (deg)
2. Axial acceleration (g's)	15. Geodetic latitude (deg)
3. Altitude (ft)	16. Longitude (deg)
4. Radius (ft)	17. Impact latitude (deg)
5. Relative velocity (ft/s)	18. Impact longitude (deg)
6. Inertial velocity (ft/s)	19. Vehicle weight (lb)
7. Dynamic pressure (psf)	20. AOA (deg)
8. Relative flight path angle (deg)	21. Sideslip angle (deg)
9. Inertial flight path angle (deg)	22. Pitch attitude command (deg)
10. Stagnation heating (BTU)	23. Yaw attitude command (deg)
11. Stagnation heating rate (BTU/s)	24. Liquid propellant consumed (lb)
12. Down range (ft)	25. Solid propellant consumed (lb)
13. Cross range (ft)	

If the trajectory is declared to be a dispersion run, the user is also asked to identify the name of the dispersion output file in the command file. The first time this dispersion file is used by MASTRE, the user must initialize the file by selecting the menu item in the Dispersions submenu (see Section 16). **Table 2-5** shows the types of dispersion runs that the RSS software has been setup to output. The IVAR parameter is an internal index used to identify the types of dispersion runs. This parameter is defined in the User Interface Software from the user's input selections. Every trajectory is allowed a maximum of 300 points; therefore, the user must be careful in the selection of the input variables.

Table 2-5. Dispersion Types

Starting address for IVAR direct access storage file				
	Value	Dispersion Type	Positive	Negative
	0010	Nominal	00001	
Propulsion	101_*	SSME vacuum thrust	00301	00601
	102_	SSME vacuum Isp	00901	01201
	103_	SSME mixture ratio	01501	01801
	104_	SSME thrust misalign (pitch)	02101	02401
	105_	SSME thrust misalign (yaw)	02701	03001
	106_	ASRM web action time	03301	03601
	107_	ASRM vacuum Isp	03901	04201
	108_	ASRM propellant loading	04501	04801
	109_	ASRM inert weight	05101	05401
	110_	ASRM thrust misalign (pitch)	05701	06001
	111_	ASRM thrust misalign (yaw)	06301	06601
	112_	ASRM thrust imbalance	06901	07201
	113_	ASRM thrust uncertainty	07501	07801
Aero/Envir	201_	Forebody axial force	08101	08401
	202_	Base force	08701	09001
	203_	Other Aerodynamic coeff	09301	09601
	204_	Wind profiles (head and tail)	09901	10201
	205_	Wind profiles (rt and lt cross)	10501	10801
	206_	Atmospheric density	11101	11401
Mass Prop	301_	Core inert weights	11701	12001
	302_	Propulsion mod inert wt	12301	12601
	303_	Core propellant weight	12901	13201
	304_	Center of gravity	13501	13801
GN&C	401_	Booster pitch steering program	14101	14401
	402_	Booster yaw steering program	14701	15001
Composite	5010	Composite (max dyn pres)	15301	
	5020	Composite (min dyn pres)	15601	
	5030	Composite (max aero heating)	15901	
	5040	Composite (min aero heating)	16201	
	5050	Composite (max altitude)	16501	
	5060	Composite (min altitude)	16801	
	5100	RSS data	18001	
* __0 - positive dispersion, __1 - negative dispersion				

The RSS Program accumulates the dispersions generated by the MASTRE Program, which are placed on the dispersion file, and calculates a composite RSS of the system and environmental dispersions. By using these RSSed values, the user can then generate composite trajectories that emulate the effects of combinations of the positive and negative dispersions. The composite trajectories generated by the user are placed in the dispersion file and are also displayed in both the output tables and the plot files.

Input to the RSS Program requires the user to provide the names of the dispersion file generated by the MASTRE Program and the output table and plot files that will be generated by the RSS Program. Additionally, the program will ask the user to define the variables that will be used to generate the RSS Program output.

Outputs of the RSS Program are an output table file and two plot files. The output tables contain publishable tables that show time ordered nominal trajectory parameters, the variations from the nominal caused by various effects, and the calculated plus and minus rss values. Two plot files are provided to allow the user to either plot many trajectory parameters on the same file or plot one parameter and various dispersion trajectories on the same file. The first plot file can include all of the parameters from **Table 2-4** and contains the nominal values, the nominal plus and minus the RSSed values, and the plus and minus composite trajectories. The second plot file allows one parameter from **Table 2-4** and contains the nominal trajectory values; the plus and minus composite trajectory values; and all, or selected, trajectory values based on the dispersions (see **Table 2-5**). The plot files must be transported to the Macintosh from the VAX such that a graphic software package, like Cricket Graph, can be used to generate plots.

2.6.4 Output Files

Three output files, FOR031.DAT, FOR021.DAT, and FOR007.DAT, are generated whenever a trajectory simulation is run. The FOR031.DAT file provides the general trajectory data consisting of printouts of the input Namelists, the iteration associated data, and block prints of time and various parameters. These outputs will be discussed in Section 19.

The FOR021.DAT file consists of the outputs generated by the weight summary tables, the gains summary tables, and the optional parameter tables. The FOR007.DAT file is an optional output file and provides a time history of propulsion related data. The elements of the FOR021.DAT and FOR007.DAT output files are discussed in the following subsections.

2.6.4.1 Weight Summary Output

The weight summary table and the gains summary table are system and mission dependent. Three weight summary tables are available that reflect anomalies of the three current types of vehicles that are modeled with the simulation. **Tables 2-6 through 2-8** provide the formats used to identify weights in the separate output tables. Data in bold type indicate that the weight values are calculated and are not included in the weight summary input tables. Input for these tables is described later in Subsection 15.1.

The gains summary table is also system dependent and only provides information relevant to the system being simulated. An additional table is output to provide information for the branch trajectory option. Stage separation related data are provided on the gains summary table. Data provided are time, altitude, relative velocity, inertial velocity, relative flight path angle, inertial flight path angle, dynamic pressure, axial acceleration, Mach number, and vehicle mass before and after separation.

2.6.4.2 Parameter Table Output

The parameter table output option provides publishable output tables that provide time histories of many of the output parameters available on the block output format. The formats and the parameters of these tables can be modified by the User Interface Program.

2.6.4.3 Propulsion Table Output

An output height table for both the liquid oxygen (LOX) and liquid hydrogen (LH2) tanks are provided as optional propulsion table output on the FOR007.DAT file. Additional inputs for outputting this table are required and will be discussed in Subsection 15.3. This option also requires two additional input files, which are defined in the command (.COM) file (see Section 17).

2.6.5 Command File Creation

The command file allows the user to specify several options to the code during execution. The inputs required by the command (.COM) file are shown in **Table 2-9**. The User Interface Program has automated the process of creating or editing the command file, which is described in Section 17. The following discussion should clarify the records of the command file.

Table 2-6. Multistage Liquid Vehicle Weight Summary Output Table

PAYLOAD *	
UPPER STAGE	- JETTISON WEIGHT - INERT STRUCTURE - FLIGHT PERFORMANCE RESERVE - DELTA VELOCITY PROPELLANT(FPS) - EXCESS PROPELLANT (PROP LD) - FUEL BIAS
WEIGHT AT ORBIT INSERTION	
UPPER STAGE - PROPELLANT BURNED	
WEIGHT AFTER 2ND STAGE SEPARATION	
PERFORMANCE MARGIN - PAYLOAD	
- OTHER	
2ND STAGE	- JETTISON WEIGHT - STAGE INERT WEIGHT (LESS ENG) - NONPROPULSIVE CONSUMABLES - DRY WEIGHT OF ENGINE(S)
2ND STAGE	- TOTAL WEIGHT AT 2ND STAGE SEP - PROP RESIDUALS/UNUSABLES - FLIGHT PERFORMANCE RESERVE - FUEL BIAS - MPS THRUST BUILDUP - BOILOFF, OVERFILL, DRAINBACK
EXCESS MPS PROPELLANT (MPS PROP LOADED)	
SHROUD WEIGHT SEPARATED AT MECO	
INJECTED WEIGHT AT MECO	
SHROUD JETTISON WEIGHT	
PROPELLANT BURNED - SEPARATION TO MECO	
WEIGHT AT SEPARATION	
1ST STAGE	- JETTISON WEIGHT - STAGE INERT WEIGHT (LESS ENG) - DRY WEIGHT OF ENGINE(S) - NONPROPULSIVE CONSUMABLES - FUEL BIAS - PROP RESIDUALS/UNUSABLES
PROPELLANT BURNED - LIFTOFF TO SEPARATION	
LIFTOFF (T/W=1.0)	
MPS PROPELLANT	
IGNITION COMMAND (T-0)	
1ST STAGE	- MPS THRUST BUILDUP - BOILOFF, OVERFILL, DRAINBACK
PRELAUNCH WEIGHT (T-5 MIN)	

***Parameters in bold letters are internally calculated based on the trajectory output, all others are supplied through the input array.**

Table 2-7. Multistage Strap-On Vehicle Weight Summary Output Table

PAYLOAD *	
UPPER STAGE	<ul style="list-style-type: none"> - JETTISON WEIGHT - INERT STRUCTURE - FLIGHT PERFORMANCE RESERVE - DELTA VELOCITY PROPELLANT - EXCESS PROPELLANT (PROP LD) - FUEL BIAS - PROP RESIDUAL/UNUSABLE
WEIGHT AT ORBIT INSERTION	
UPPER STAGE - PROPELLANT BURNED	
WEIGHT AFTER 2ND STAGE SEPARATION	
PERFORMANCE MARGIN	<ul style="list-style-type: none"> - PAYLOAD - OTHER
2ND STAGE- JETTISON WEIGHT	
	<ul style="list-style-type: none"> - STAGE INERT WEIGHT (LESS ENG) - NONPROPULSIVE CONSUMABLES - DRY WEIGHT OF ENGINE(S)
2ND STAGE-TOTAL WEIGHT AT 2ND STAGE SEP	
	<ul style="list-style-type: none"> - PROP RESIDUALS/UNUSABLES - FLIGHT PERFORMANCE RESERVE - FUEL BIAS - MPS THRUST BUILDUP - BOILOFF, OVERFILL, DRAINBACK
EXCESS MPS PROPELLANT (MPS PROP LOADED)	
SHROUD WEIGHT SEPARATED AT MECO	
INJECTED WEIGHT AT MECO	
SHROUD JETTISON WEIGHT	
PROPELLANT BURNED - SEPARATION TO MECO	
WEIGHT AT SEPARATION	
1ST STAGE	<ul style="list-style-type: none"> - JETTISON WEIGHT - STAGE INERT WEIGHT (LESS ENG) - DRY WEIGHT OF ENGINE(S) - NONPROPULSIVE CONSUMABLES - FUEL BIAS - PROP RESIDUALS/UNUSABLES
STRAP-ON	<ul style="list-style-type: none"> - JETTISON WEIGHT - INERT MOTOR WEIGHT (LESS ENG) - DRY WEIGHT OF ENGINE(S) - NONPROPULSIVE CONSUMABLES - FUEL BIAS - PROP RESIDUALS/UNUSABLES - INERTS CONSUMED (SRM ONLY)
PROPELLANT BURNED - LIFT-OFF TO SEPARATION	
MPS	
SRM	
LIFTOFF (T/W=1.0)	
MPS PROPELLANTS	
STRAP-ON PROPELLANT	
IGNITION COMMAND (T-0) WEIGHT	
MPS	<ul style="list-style-type: none"> - THRUST BUILDUP - BOILOFF, OVERFILL, DRAINBACK
PRE LAUNCH WEIGHT (T-5 MIN)	

*Parameters in bold letters are internally calculated based on the trajectory output, all others are supplied through the input array.

Table 2-8. Space Shuttle Weight Summary Output Table

PAYLOAD *	
OMS KIT	
MISSION KIT	
ORBITER	- EMPTY
	- NONPROPULSIVE CONSUMABLES
	- USABLE RCS (RCS LOADED)
	- RCS RESERVES
	- RCS RESIDUALS
	- USABLE OMS (OMS LOADED)
	- OMS PROPELLANT (DEORBIT)
	- OMS RESERVES
	- OMS RESIDUALS
SSME EMPTY	
ORBITER AT ORBIT INSERTION	
MECO OMS MANEUVER- OMS PROPELLANT	
	- RCS PROPELLANT
TRAPPED MPS PROPELLANT- ORBITER	
	- SSME
FLIGHT PERFORMANCE RESERVE- ORBITER	
	- SSME
ORBITER AT OMS IGNITION	
RCS PROPELLANT- ET SEPARATION	
EXTERNAL TANK - EMPTY	
	- RESIDUALS
FLIGHT PERFORMANCE RESERVE - ET	
FUEL BIAS	
EXCESS MPS PROPELLANT (MPS PROP LOADED)	
EXPULSED MPS PROPELLANT	
INJECTED WEIGHT AT MECO	
PROPELLANT BURNED - AOA/RTLS TO MECO	
TOTAL VEHICLE WEIGHT AFTER SRM SEPARATION- MPS	
	- OMS
	- RCS
OMS PROPELLANT DUMPED (RCS BURN)	
EXPULSED MPS PROPELLANT	
WEIGHT AT AOA/RTLS	
MPS PROPELLANT BURNED - LBM SEPARATION ** TO RTLS/AOA	
WEIGHT AT LBM SEPARATION	
LBM INERT WEIGHT	
PROPELLANT BURNED - SRM SEPARATION TO	- LBM SEPARATION
	- MPS
	- LBM
ET+ORBITER AFTER SRM SEPARATION	
SRM INERT WEIGHT	
SRM RESIDUAL PROPELLANT	

Table 2-8. Space Shuttle Weight Summary Output Table (Concluded)

INERTS CONSUMED	
PROPELLANT BURNED - LBM IGNITION TO SRM SEPARATION-	MPS
	- LBM
	- SRM
LBM IGNITION (T+5 SEC)	
PROPELLANT BURNED - LIFTOFF TO LBM IGNITION-	MPS
	- SRM
LIFTOFF (T/W=1.0)	
SRB PROPELLANTS	
SRB INERTS	
MPS PROPELLANT	
SRB IGNITION COMMAND (T-0)	
MPS THRUST BUILDUP + SRM IGNITION DELAY	
OVERFILL, DRAINBACK, AND BOILOFF	
NON PROPULSIVE CONSUMABLES	
PRE LAUNCH WEIGHT (T-5 MIN)	
*Parameters in bold letters are internally calculated based on the trajectory output; all others are supplied through the input array.	
**LBM data are only printed when the LBM is being simulated	

The records that begin "\$WRITE SYS\$OUTPUT" are used by the VAX system as optional title identification and are treated as nonexecutable instructions. Text is placed within quotes (" ") at the end of this declaration. The number of these lines is optional to the user. When creating a command, the User Interface Program defines one comment line as a title. If the user desires more of these lines, an edit feature is available to include additional comment lines. The comment lines are terminated by the "\$RUN" request record. This record defines the version and location of the MASTRE Program that will be used in the simulation.

After the "\$RUN" record, the next record indicates the answer to the question "**Do you want a print file?**". This print file is the FOR031.DAT file that contains the trajectory run output.

The next line indicates the answer to a question "**Are you at a graphics terminal?**". The user should always place a "YES" answer. The next line relates to this question since the user is asked to choose between a batch operation (=1) or a demand (=2) mode. The next line (as well as other lines at the end of the command file) is the answer to a menu of options that the user can select. These options are: 0-terminate, 1-execute, 2-select Namelist data input, 3-write file for plots and tables, and 4-printout menu. By indicating a value of 2, the input variables will be read. In most cases, since the answers to the above requests very rarely change, the User Interface Program defaults to the values shown in **Table 2-9**. The records in **Table 2-9** define input and output file names that are needed by the MASTRE Program during execution.

Table 2-9. Command (.COM) File Input Options

COM File Record	Description
\$WRITE SYS\$OUTPUT " "	
\$WRITE SYS\$OUTPUT " TITLE OF RUN"	
.	
.	
.	
\$RUN [dir.subdir] MASTRE	
YES *or NO	[Do you want a print file ?]
YES or NO	[Are you at a graphics terminal ?]
1 or 2	[1- batch, 2-demand]
0, 1, 2, 3, or 4	[0-terminate,1-execute, 2-select plots and tables,
Namelist data input, 3-write file for	4-printout menu]
YES or NO (yes or no)**	[Will a nonlinear aero data base be input?]
(Aero data base file name)	[Only input if YES (or yes) answer]
Aero Namelist file name	[Aerodynamic Namelist file]
Weight Namelist file name	[Weights Namelist]
YES or NO (yes or no)	[Are SRMs to be simulated?]
(SRM data base file name)	[Only input if YES (or yes) answer]
Trajectory Namelist file name	[Trajectory Namelist]
(Alternate mass properties file name)	[Only input if alternate mass properties flag is on]
YES or NO (yes or no)	[Is plot file to be generated?]
(Plot file name)	[Only input if YES (or yes) answer]
(Dispersion file name)	[Only input if "ivar" nonzero]
(First-stage jump-start file name)	[Only input if first-stage jump-start is requested]
(LOX tank height file name)	[Only input if propulsion output table requested]
(LH2 tank height file name)	[Only input if propulsion output table requested]
0, 1, 2, 3, or 4	[0-terminate, 1-execute , 2-select Namelist data input,
	3-write file for plots and tables, 4-printout menu]
0, 1, 2, 3, or 4	[0-terminate , 1-execute, 2-select Namelist data input,
	3-write file for plots and tables, 4-printout menu]
0, 1, 2, or 3	[0-do not print and delete output FOR031.DAT file,
	1-do not print but save delete FOR031.DAT file and,
	3-print
FOR031.DAT file , 2-print and and save FOR031.DAT file]	
* BOLD values are to used as defaults	
**() Optional input or based on input values	

The next record answers the question **"Will a nonlinear aero data base be input?"**. The aero data base referred to is the nonlinear aerodynamic data base (direct access file) used by the Space Shuttle. If a "Y" or "y" is present, the name of the data base is required on the next record of the .COM file. Otherwise, the next record is related to the next input.

The next record asks the user to specify the name of the aerodynamic input Namelist file. This file contains nonlinear and linear aerodynamic coefficients and data associated with base force data. The Namelist name associated with this data is "\$AEROIN".

The next record asks the user to specify the weight Namelist file that provides the weight summary information for the weight summary tables and provides pertinent data for several of the program options. The Namelist name associated with this data is "\$WEIGHTS".

The next record is again the answer to a question with a logical variable. The question is **"Are SRMs to be simulated?"**. If a "Y" or "y" is present, the name of the SRM data base file is required on the next record of the .COM file. This file contains time-dependent tables of thrust, flowrate, and exit area data for the SRM.

The next record contains the file name of the general Namelist file. The Namelist name associated with this data is "\$INPUT".

The next record is optional and defines the file name of the alternate mass properties input file. This file is obtained by running the Mass Properties User Interface Program (see Appendix A). To use this input file, the user must specify this choice in the input (see Section 10).

The next record answers the question **"Is a plot file to be generated?"**. If a "Y" or "y" is present, the name of the output plot file is required on the next record of the .COM file. The plot file outputs all of the trajectory block output parameters (see Section 19) from the converged, or final, trajectory.

The next four records are only required if certain option flags are set in the input. All, part, or none of these lines can be input by the user. The first set is a single line that is only required if the dispersion option flag is not equal to zero. A nonzero value requires that the user specify the name of the dispersion data file, which will be used to store trajectory data. The second record is required if a first-stage jump-start is being implemented. Jump-start conditions are saved on an output file if the first-stage jump-start time variable is greater than zero, and the launch time is equal to zero. The jump-start is activated if the jump-start variable flag is equal to 1 and the launch time is greater than 0.1 (the launch time value should correspond to one of the jump-start times on the input file). The name of the input or output file is provided by the user in this record of the .COM file if this option is

used. The third and fourth records specify the names of the LOX and LH2 tank height tables, respectively. These names are only required if the propulsion output table option is to be used.

The next record again answers the menu described above. The value of 1 is used to begin execution of the program. The next record answers the same menu with a zero value, which indicates termination of the run.

The last record indicates the user's desire for the status of the output FOR031.DAT file. The options are shown in *Table 2-9*. Options 2 and 3 are not operational.

3. USE OF USER INTERFACE PROGRAM

This section provides a tutorial for implementing the User Interface Program and discusses the use of special options.

The user begins the execution of the User Interface Program by the command "RUN UFI". This command initiates the program and the words "MASTRE USER INTERFACE" (see **Figure 3-1**) appear on the screen. To clear the screen, the user must press the Return Key. The next screen (see **Figure 3-2**) requests the user to select the directory and subdirectory where the Namelist file resides. The user has the choice of using the default directory/subdirectory or typing in the appropriate directory/subdirectory. After specifying the directory/subdirectory location, the computer searches and displays the available general input Namelist files as shown in **Figure 3-3** (the assumption is that a general input Namelist file exists). The selection is made by moving the cursor, via the arrow keys, to the required file name and pressing the Return Key. After selection of the general input Namelist file the user must select the vehicle system to be simulated and the mission scenario. The selection is made from menus as illustrated in **Figure 3-4**. Currently, the vehicle systems available are a Multistage Liquid Vehicle, a Multistage Solid-Rocket Booster (SRB) Vehicle, or the Space Shuttle. Following the simulation options, the user is asked to define a header that will be use on each page of the printout. If the existing header is sufficient, the user can press the Return key and continue.

MASTRE USER INTERFACE

Figure 3-1. Initial Interface Menu

Select Directory

Default Directory is [MASTRE.UFI]

Enter directory or hit return for default

==>

Figure 3-2. Directory Request Menu

After selection of the vehicle system, the mission scenario, and the header, the next screen provides the main menu (see **Figure 3-5**), which the user can select from any of the 17 items. If the

user wishes to exit the program at any time, the "Quit" selection should be made on the main menu. Once the "Quit" selection is made, the user is asked, if changes have been made and not saved, if a new MASTRE input file is to be created or the old file updated. If a new file is to be created, the user must supply a file name. The program is terminated either after supplying the file name, pressing the Return Key, or a negative answer to the question.

Select File

Please wait, I am looking for .inl files

XXXX.inl	XXXX.inl	XXXX.inl	XXXX.inl
XXXX.inl	XXXX.inl	XXXX.inl	XXXX.inl
XXXX.inl			

Figure 3-3. Files Search Menu

Simulation Options

Multi-Stage Liquid Vehicle
Multi-Stage SRM Vehicle
Space Shuttle

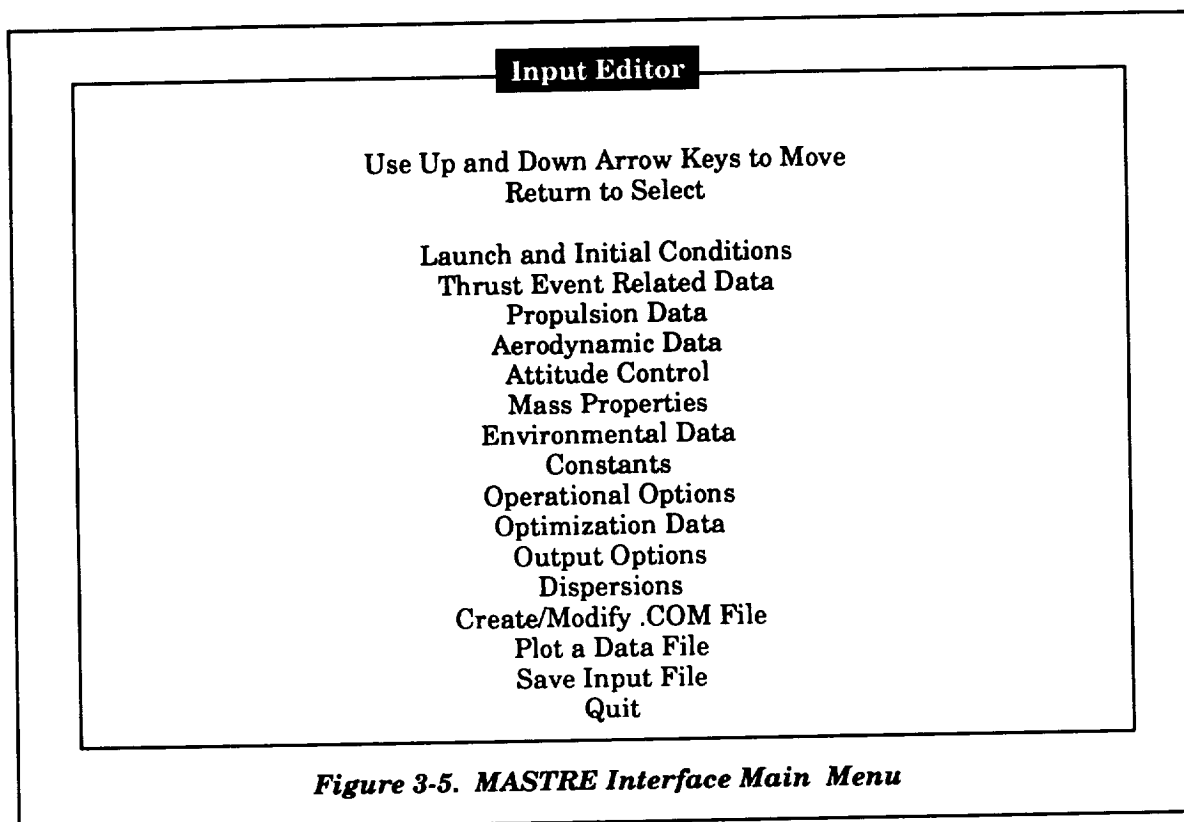
Simulation Options

Nominal Trajectory
Engine-Out Trajectory
Branch Traj Eng-Out/Nominal
Branch Traj Nominal/Eng-Out

Define Header

Current Header (hit return if no change)
TRAJECTORY title
==>

Figure 3-4. Simulation Option Menus



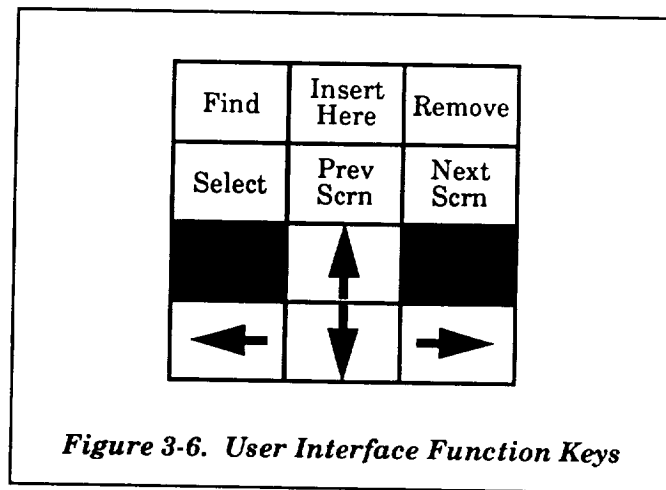
Modification of the current file or creation of a new file is also optional to the user after making changes to the parameters defined under the main menu. The user also can save the current data at any time during execution by selection of the "Save Input File" item on the main menu. During execution of the program, the user is asked if he wishes to save the input files after modification of these files.

To modify and review the data, the user must be familiar with the special function keys used by the software. The next paragraphs provide a summary of their use and provide special instructions for use of the program.

3.1 FUNCTION KEYS

To use the User Interface Program, an extended keyboard is required that contains the function keys located between the number keypad and the typewriter keys. These function keys contain the cursor arrow keys and a grouping of special keys to perform different functions. **Figure 3-6** shows a layout of these keys. Special keys used by the User Interface Program are the Select Key, the Remove Key, the Insert Here Key, the Next Scrn (Next Screen) Key, the Prev Scrn (Previous Screen)

Key, the Find Key, and the Return Key. The following paragraphs define the purpose of these special keys.



3.1.1 Return Key

The Return Key is used to either terminate a window or denote the completion of data entry when using either the Select Key or the Find Key.

3.1.2 Cursor Arrow Keys

The Cursor Arrow Keys are used to move the cursor on the screen in the direction denoted by the arrow. The arrow keys are used for both menus and data tables. Menus primarily use the up and down Arrow Keys, whereas the data tables use the up, down, left, and right Arrow Keys. Scrolling of a data table that continues off the screen is performed by continued pressing of either the up or down Arrow Keys. Once the bottom, or top, of the table is reached, continued pressing in the same direction will not move the cursor. Scrolling of a menu, however, is different since continued pressing in the same direction of the up or down Arrow Keys when at the top or bottom of the menu will send the cursor to either the bottom or top of the menu, respectively.

3.1.3 Select Key

The Select Key is used to select data on the screen that will be modified. The user must use the Arrow Keys to select the data to be modified, by high-lighting the selection with the cursor and pressing the Select Key. Once the Select Key is pressed, the user is prompted by a string of minus signs (i.e., "----"), the number of minus signs being a function of the number of digits displayed by the data table. The user is limited in the input values to the number of digits displayed. If the user

indiscriminately presses the Select Key while scanning the data, the original value can be retrieved by pressing the Return Key. If the user, while modifying data, puts an erred number (i.e., a number containing an alphabetic or special character (other than a decimal point, the letters 'E' or 'D', or a plus or minus sign) the string of minus signs will reappear. The user can either recall the original number by pressing the Return Key or type a corrected entry.

3.1.4 Remove Key

The Remove Key is used only when data are displayed in a tabular fashion. By placing the cursor, via the arrows keys, over any element in a row and pressing the Remove Key, all values contained in the rows below the indicated row are moved up, thus removing the indicated row.

3.1.5 Insert Here Key

The Insert Here Key is also used only when data are displayed in a tabular fashion. By placing the cursor, via the arrows keys, over any element in a row and pressing the Insert Here Key, all values contained in the indicated row as well as all rows below the indicated row are moved down. Zero values or blanks (depending on whether the data are numeric or characters) are placed in the inserted row (which can be changed by the user).

3.1.6 Next Scrn Key

The Next Scrn Key is used when there are multiple windows on a single screen. When multiple windows are present, the initial placement of the cursor indicates the "home" window. The Next Scrn Key is used to move the cursor from one window to the next. Once the cursor is transferred to a window, the arrow keys can then be used to move the cursor on the new window.

3.1.7 Prev Scrn Key

The Prev Scrn Key is also used when there are multiple windows on a single screen. The Prev Scrn Key allows the user to transfer back from a current window to the "home" or previous window.

3.1.8 Find Key

The Find Key is used in the command file generation section of the User Interface Program (see Section 17) to allow the user to selectively pick from a list of available files when creating or editing a command file.

3.2 FILE MANAGEMENT

File management in the User Interface Program is simplified for the user by menus that provide a listing of the current files resident in the directory/subdirectory specified by the user. To eliminate the confusion of the user identifying the names of multiple files to provide different types of input, input and output files are identified by a variety of extensions that are required for use in the User Interface Program. **Table 3-1** provides a listing of the extensions for each of the input and output types.

Table 3-1. File Extension Definitions

Extension	File Type
INL	General input Namelist file
ANL	Aerodynamic data Namelist file
ADB	Nonlinear aerodynamic data base
WNL	Weight summary Namelist file
DSP	Dispersion parameter file
PLT	Output plot file
JUM	First-stage jump-start input or output file
LOX	LOX input file for special propulsion output
LH2	LH2 input file for special propulsion output
SRM	SRM thrust input file
SMI	SRM mass properties input file
SMM	SRM mass properties output file
TEI	MPS (throttle) mass properties input file
TEM	MPS (throttle) mass properties output file
NEI	MPS (non-throt) mass properties input file
NEM	MPS (non-throt) mass properties input file
HMI	Hybrid engine mass properties input file
HMM	Hybrid engine mass properties output file
MRG	Merge (mass properties) input file
MMM	Merge (mass properties) output file

Inputting files are provided via menus. **Figure 3-3** provided an example of the menu used for file selection. The user selects the required file by moving the cursor, via the arrow keys, to the desired file name and pressing the Return Key.

When creating a file within the program, the user does not have to add the extension. The program will add the proper extension unless the user provides an extension denoted by a decimal point in the file name. **(Warning: When the user is defining an input file name, the file name should not contain a decimal point unless an extension is added.)**

3.3 SCROLLING

Because of the size of many of the input arrays or input items, the data tables associated with these arrays occupy more than the screen can display. When this occurs, the program allows the user to scroll through the tables. This is done by continuously pressing either the up or down Arrow Keys.

4. **LAUNCH AND INITIAL CONDITIONS**

The Launch and Initial Conditions menu (see **Figure 4-1**) consists of parameters associated with launch geometric conditions and initial conditions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, hitting the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The definitions of these parameters are defined in **Table 4-1**.

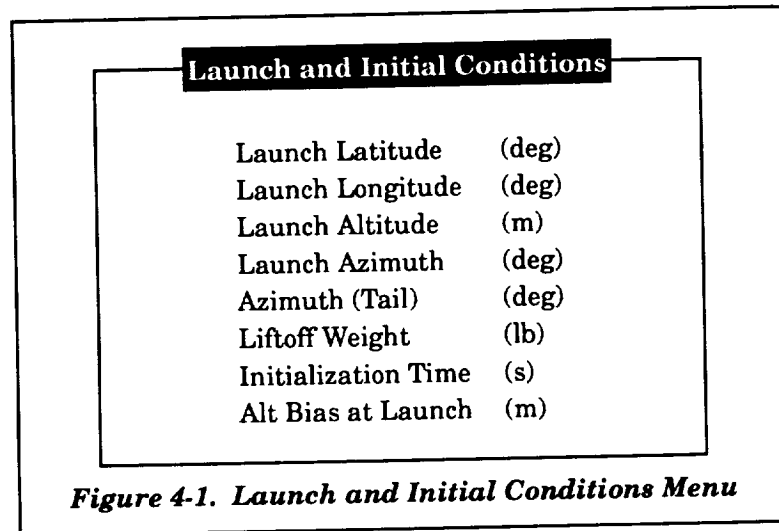


Table 4-1. Launch and Initial Conditions

Parameter	Description	Units
Launch Latitude	Geodetic latitude of launch site	deg
Launch Longitude	Longitude of launch site	deg
Launch Altitude	Altitude of launch site above reference ellipse	m
Launch Azimuth	Definition of launch azimuth used to define launch plumbline coordinate system	deg
Azimuth (tail)	Azimuthial angle of Orbiter tail at launch (used when simulating Space Shuttle)	deg
Liftoff Weight	Total lift-off weight of vehicle at liftoff	lb
Initialization Time	Time after lift-off to begin simulation (nonzero if jump start simulation)	s
Altitude bias at launch	Altitude bias used to calculate base force	m

5. THRUST EVENT RELATED DATA

Parameters associated with thrust events are defined in this section. **Figure 5-1** provides a display of the parameters, and **Table 5-1** provides the definitions of the parameters under this section. As shown in **Figure 5-1**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the thrust events (maximum of 15 thrust events). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key.

Thrust Event Related Data							
Thrust Evt Time (s)	Jettison Wtg (lb)	Reference Area (m2)	Print Interval (s)	Forward Step Size (s)	Backward Step Size (s)	Wt Drop Time (s)	Drop Wt (lb)
XXX.XX	XXXXXX.X	XX.XX	XX.XX	XX.XX	XX.XX	XXX.XX	XXXXX.
XXX.XX							
XXX.XX							
XXX.XX							
XXX.XX							
XXX.XX							
XXX.XX							

Figure 5-1. Thrust Event Related Data Menu

If the user wishes to either delete or add a thrust event, the user should place the cursor, via the Arrow Keys, over any element of the desired row. Using the Remove Key, the selected row will be deleted and all subsequent rows will be moved up. Using the Insert Here Key, the selected row will be moved down along with the subsequent rows. The selected row will display zero values that can be modified by the user. When deleting or adding thrust events, the user should be careful to change other thrust event related data (i.e., general propulsion data associated with thrust events, thrust events per stage, attitude control phases, etc.).

As shown in **Table 5-1**, the user can use either the jettison weight parameter or the drop weight parameter to simulate the jettisoning or dropping of weight at some time. The jettison weight parameter is used if the user wishes to jettison the weight at the end of the thrust event. This is especially useful if the time interval of the thrust event is an optimization variable that allows the time

interval to be modified. The drop weight parameter allows the user to drop the weight during the thrust event by defining the drop weight time interval. The drop weight time interval is not an optimization parameter and, therefore, does not vary. In most cases, the jettison parameter is the parameter of choice since additional thrust events can be used to provide variable weight drop events.

Table 5-1. Thrust Event Related Data

Parameter	Description	Units
Thrust Evt Time	Time interval for each thrust event	s
Jettison Wtg	Weight to jettison at the end of thrust event per thrust event	lb
Reference Area	Aerodynamic reference area per thrust event	m ²
Print Interval	Print interval per thrust event	s
Forward Step Size	Integration step size for forward integration per thrust event	s
Backward Step Size	Integration step size for backward integration per thrust event	s
Wt Drop Time	Time interval from beginning of thrust event to drop weight per thrust event	s
Drop Wt	Amount of weight to drop at weight drop time per thrust event	lb

6. STAGE RELATED DATA

Parameters associated with stages are defined in this section. **Figure 6-1** provides a display of the parameters, and **Table 6-1** provides the definitions of the parameters under this section. As shown in **Figure 6-1**, a matrix of data is displayed with the columns representing each of the stages (maximum of five stages) and the rows representing the parameters. Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features discussed in Section 5 are not used on this data table.

Stage Related Data					
Stages	1	2	3	4	5
Number of Thrust Events					
Propellant Termination					
Branch Option - Optimization					
Flight Perf Reserve Factor					
Characteristic Velocity (fps)					
1st Level of Constant Throt					
2nd Level for Constant Throt					
3rd Level for Constant Throt					
4th Level for Constant Throt					
5th Level for Constant Throt					
6th Level for Constant Throt					
7th Level for Constant Throt					
8th Level for Constant Throt					
9th Level for Constant Throt					
10th Level for Constant Throt					

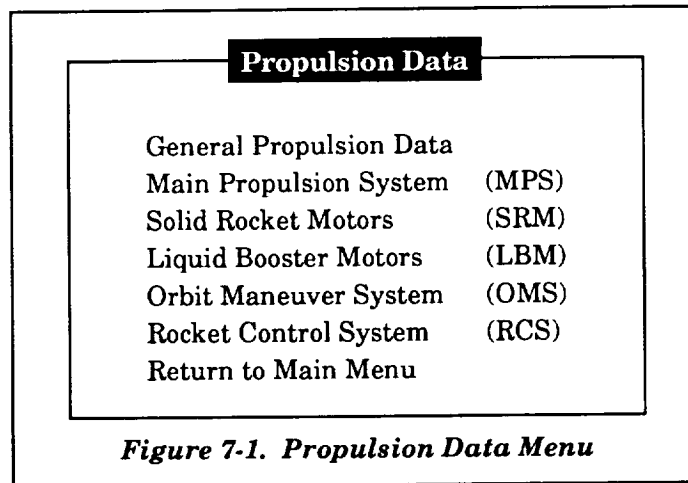
Figure 6-1. Stage Related Data Menu

Table 6-1. Stage Related Data

Parameter	Description	Units
Number of Thrust Events	Number of thrust events per stage	---
Propellant Termination	Nonzero value will indicate that the stage will terminate on propellant (the amount of propellant is based on the propellant weight defined in Section 7 less the inert propellants defined in Section 15)	---
Branch Option - Optimization	Nonzero value will indicate that the stage will be the branch portion of the branch trajectory. The value indicates which intermediate constraint will be used to terminate the stage (see Branch Trajectory Option under Section 13).	---
Flight Performance Reserve Factor	Multiplier factor used to calculate the flight performance reserve per stage	---
Characteristic Velocity	Characteristic velocity that is multiplied by factor to calculate flight performance reserve	ft/s
nth Level for Constant Throt	Constant throttle level used for constant MPS throttle option (10 levels are available)	---

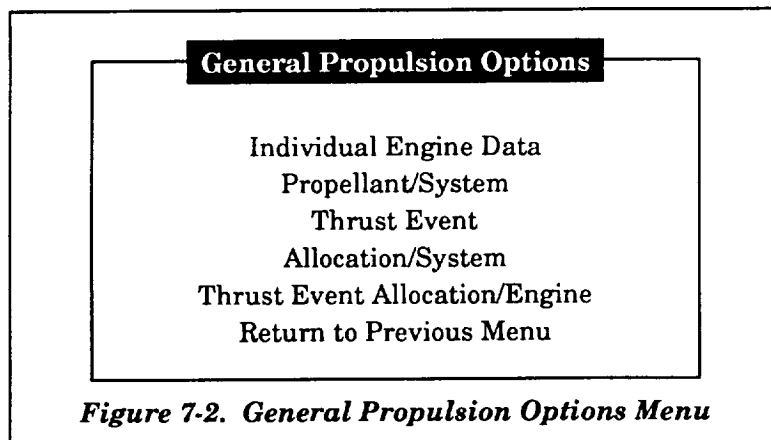
7. PROPULSION DATA

If the user selects the "Propulsion Data" item in the main menu, the submenu shown in **Figure 7-1** is displayed. This submenu defines the types of propulsion systems and the associated propulsion related data available to the user. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item. The items in the submenu are discussed in the next paragraphs.



7.1 GENERAL PROPULSION DATA

The "General Propulsion Data" item of the propulsion systems submenu is used to define general information about the five available propulsion systems. The submenu shown in **Figure 7-2** is displayed to provide the various input tables under this item. Input tables associated with the "Individual Engine Data" define the propulsion type, location, and propulsion related data. The "Propellant/System" data provide the propellant mass associated with each of the five propulsion systems. The "Thrust Event Allocation/System" data define (for each thrust event) the allocation of engines based on propulsion system. The "Thrust Event Allocation/Engine" data define which engines are assigned to each thrust event. The user is returned to the submenu after exiting each of the selections. To return to the "Propulsion Data" submenu, the user must select the "Return to Previous Menu" item. The following paragraphs will describe the contents of these data tables and explain how the user can review and/or modify the data.



7.1.1 Individual Engine Data

Parameters associated with individual engine data are defined in this subsection. **Figure 7-3** provides a display of the parameters, and **Table 7-1** provides the definitions of the parameters under this subsection. As shown in **Figure 7-3**, a matrix of data is displayed with the columns representing the parameters and the rows representing each engine (maximum of 15 engines). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

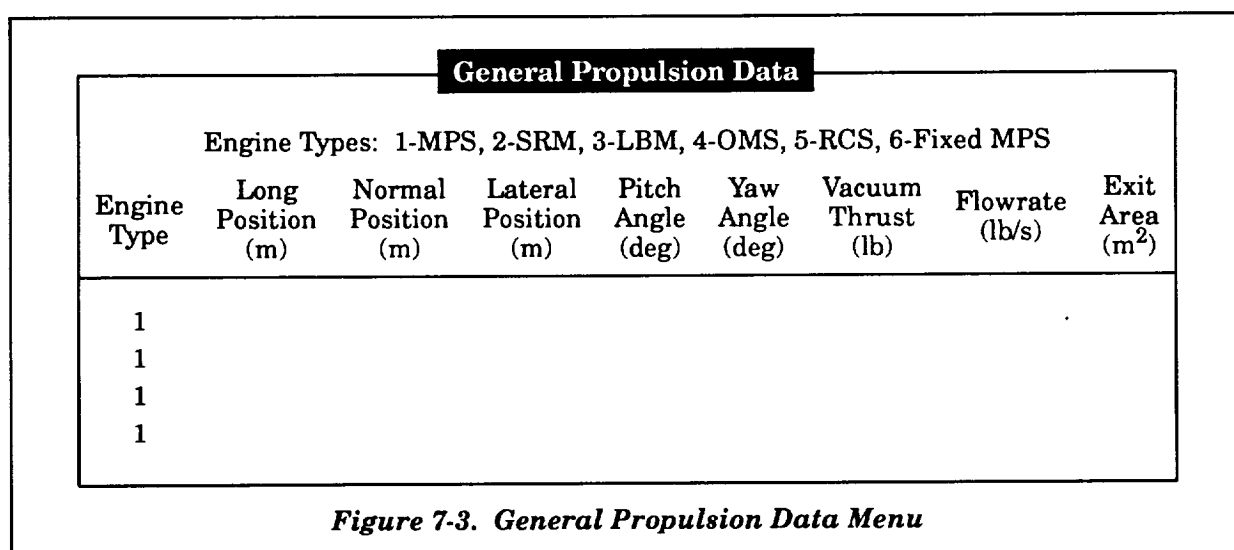


Table 7-1. Individual Engine Data

Parameter	Description	Units
Engine Type	Engine type flag: 1 - MPS, 2 - SRM, 3 - LBM, 4 - OMS, 3 - RCS, 6 - Fixed MPS	---
Long Position	Longitudinal position of engine gimbal point	m
Normal Position	Normal position of engine gimbal point	m
Lateral Position	Lateral position of engine gimbal point	m
Pitch Angle	Pitch cant angle if fixed engine	deg
Yaw Angle	Yaw cant angle if fixed engine	deg
Vacuum Thrust	Vacuum thrust of engine	lb
Flowrate	Propellant flowrate of engine	lb/s
Exit Area	Exit area of engine	m ²

7.1.2 Propellant Per System

Parameters associated with propulsion system propellant are defined in this subsection. **Figure 7-4** provides a display of the parameters, and **Table 7-2** provides the definitions of the parameters under this subsection. As shown in **Figure 7-4**, data are displayed representing each of the propellant systems. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Propellant System	
Main Propulsion System Prop	(lb)
Solid Rocket Motor Prop	(lb)
Liquid Booster Module Prop	(lb)
Orbit Maneuver System Prop	(lb)
Rocket Control System Prop	(lb)

Figure 7-4. Propellant Menu

Table 7-2. Propellant Weight Data

Parameter	Description	Units
Main Propulsion System Prop	MPS total propellant weight	lb
Solid Rocket Motor Prop	Solid propulsion system total propellant weight	lb
Liquid Booster Module Prop	LBM propellant weight	lb
Orbit Maneuver System Prop	OMS propellant weight	lb
Rocket Control System Prop	RCS propellant weight	lb

7.1.3 Thrust Event Dependent Allocation Per System

Parameters associated with thrust event related data are defined in this subsection. **Figure 7-5** provides a display of the parameters under this subsection. As shown in **Figure 7-5**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the thrust events (maximum of 15 thrust events). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key.

General Propulsion Data

The number of engines of each propulsion system per thrust event

Thrust Event	MPS	SRM	LBM	OMS	RCS	Fixed MPS
1						
2						
3						
•						
•						
•						
15						

Figure 7-5. Thrust Event Allocation Per System Menu

The insert and delete features previously discussed are available on this data table. If adding or deleting records, the user should be sure to change other thrust event related data in other menus.

7.1.4 Thrust Event Dependent Allocation Per Engine

Parameters associated with thrust event dependent engine allocation data are defined in this subsection. **Figure 7-6** provides a display of the parameters under this subsection. As shown in **Figure 7-6**, a matrix of data is displayed with the columns representing each of possible 15 engines and the rows representing zero and nonzero values, which indicate passive or active engines, respectively, for each thrust event (maximum of 15 thrust events). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

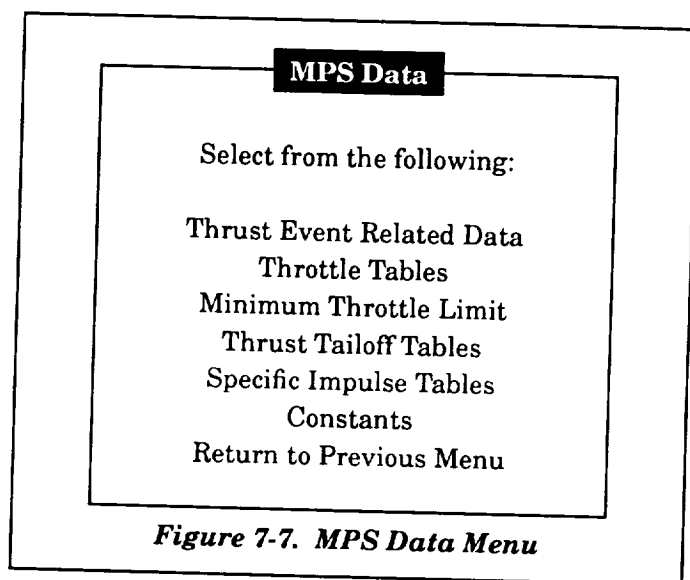
Engines/Thrust Event															
Thrust Event Number	<u>Engine Numbers</u>														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2															
•															
•															
•															
15															

Figure 7-6. Engines Per Thrust Event Menu

7.2 MAIN PROPULSION SYSTEM

If the "Main Propulsion System" item is selected under the propulsion system submenu, the submenu shown in **Figure 7-7** is displayed. Items under this submenu provide the inputs for the various MPS propulsion options available to the user. The thrust options are defined by the user as a function of thrust event and are described under the "Thrust Event Related Data" input tables. These thrust options directly relate to the "Throttle Tables" and "Thrust Tailoff Tables" item input tables. The input table under the "Minimum Throttle Limit" item provide an altitude dependent method of

limiting the minimum value of the throttle. The "Specific Impulse Tables" item provides a stage dependent method for allowing specific impulse to be a function of time from lift-off. The "Constants" item provides additional data. The user is returned to the submenu after exiting the selected item. To return to the "Propulsion Data" submenu, the user must select the "Return to Previous Menu" item. The following subsections define the input parameters and the user requirements to review and/or modify the data.



7.2.1 Thrust Event Related Data

Propulsion parameters associated with MPS thrust event related data are defined in this subsection. **Figure 7-8** provides a display of the parameters, and **Table 7-3** provides the definitions of the parameters under this subsection. As shown in **Figure 7-8**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the thrust events (maximum of 15 thrust events). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

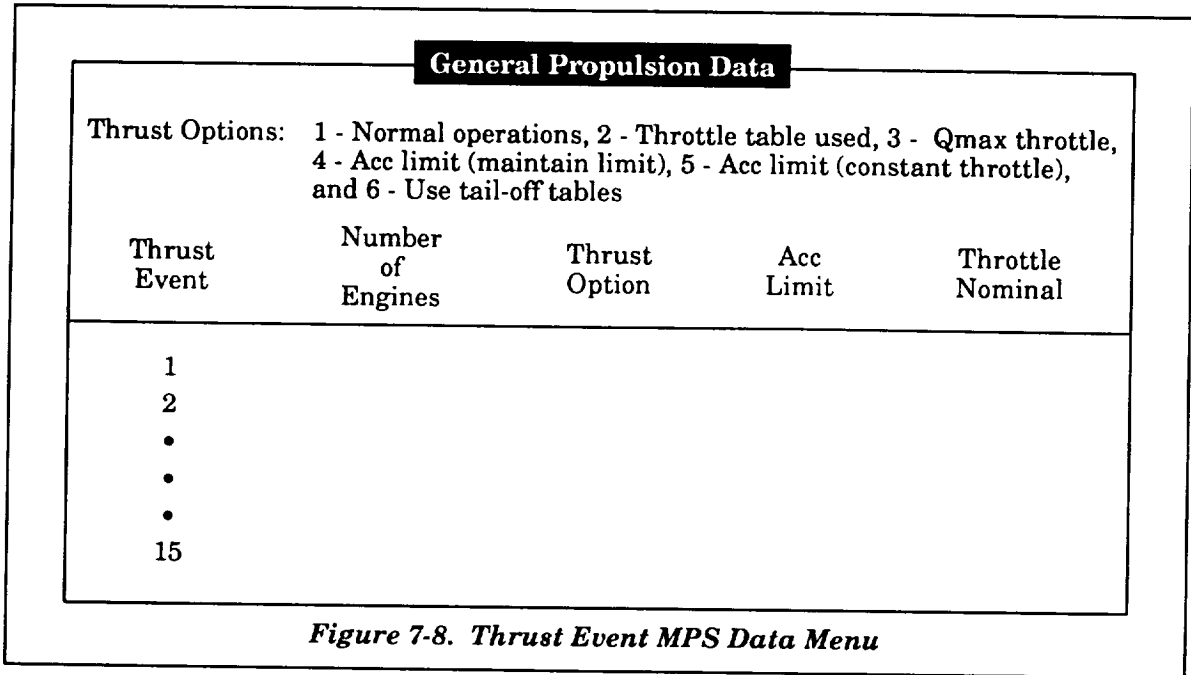


Table 7-3 . MPS Thrust Event Data

Parameter	Description	Units
Number of Engines	Total number of MPS engines per thrust event	---
Thrust Option	MPS thrust option per thrust event: 1. Uses nominal throttle value; 2. Uses throttle table; 3. Uses throttle table that allows variable times and values to impose maximum dynamic pressure constraint; 4. Uses nominal throttle value until acceleration limit is reached, after which throttle is varied to maintain constant acceleration; 5. Same as four but throttle after acceleration limit is based on stage dependent constant values (see Section 6); 6. Uses thrust tailoff tables on throttled engines and nominal values of MPS throttle	---
Acc Limit	Acceleration limit used for thrust options 4 and 5 per thrust event	g's
Throttle Nominal	Nominal value of throttle used for MPS engines per thrust event	---

7.2.2 Throttle Tables

Parameters associated with MPS throttle tables are defined in this subsection. **Figure 7-9** provides a display of the parameters, and **Table 7-4** provides the definitions of the parameters under

this subsection. As shown in **Figure 7-9**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 15 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Throttle Table		
Index	Time Table (s)	Throttle Table (---)
1		
2		
•		
•		
•		
15		

Figure 7-9. Throttle Table Menu

Table 7-4. MPS Throttle Tables Data

Parameter	Description	Units
Time Table	Time from lift-off	s
Throttle Table	MPS throttle factor	---

7.2.3 Minimum Throttle Limit

Parameters associated with MPS minimum throttle data are defined in this subsection. **Figure 7-10** provides a display of the parameters, and **Table 7-5** provides the definitions of the parameters under this subsection. As shown in **Figure 7-10**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of five data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key.

pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

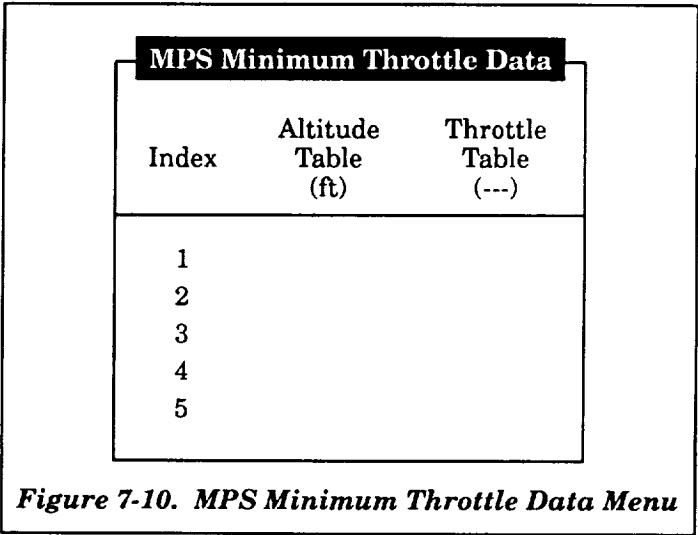


Table 7-5. MPS Minimum Throttle Data

Parameter	Description	Units
Altitude Table	Altitude table	ft
Throttle Table	Minimum MPS throttle value	---

7.2.4 Thrust Tailoff Tables

Parameters associated with MPS thrust tailoff data are defined in this subsection. **Figure 7-11** provides a display of the parameters, and **Table 7-6** provides the definitions of the parameters under this subsection. As shown in **Figure 7-11**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 15 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

MPS Tailoff Data

Index	Time Table (ft)	Throttle Table (---)	Engines To Throt (---)
1			
2			
•			
•			
•			
15			

Figure 7-11. MPS Tailoff Data Menu

Table 7-6. MPS Thrust Tailoff Data

Parameter	Description	Units
Time Table	Relative time from beginning of thrust event	s
Throttle Table	MPS tailoff throttle value	---
Engines to Throt	Number of MPS engines to throttle	---

7.2.5 Specific Impulse Tables

Parameters associated with MPS Specific Impulse are defined in this subsection. **Figures 7-12 and 7-13** provide a display of the parameters, and **Table 7-7** provides the definitions of the parameters under this subsection. As shown in **Figures 7-12 and 7-13**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of three tabular values). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. The first- through third-stage data shown in **Figure 7-12** is the first data displayed. To exit to the fourth- and fifth-stage specific impulse (Isp) table (**Figure 7-13**), the user presses the Return Key. Modifications to this table are performed in the same manner. To exit this window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

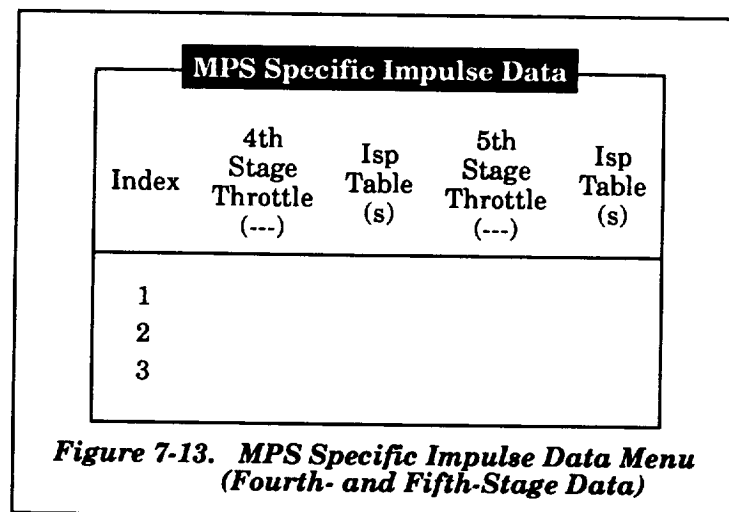
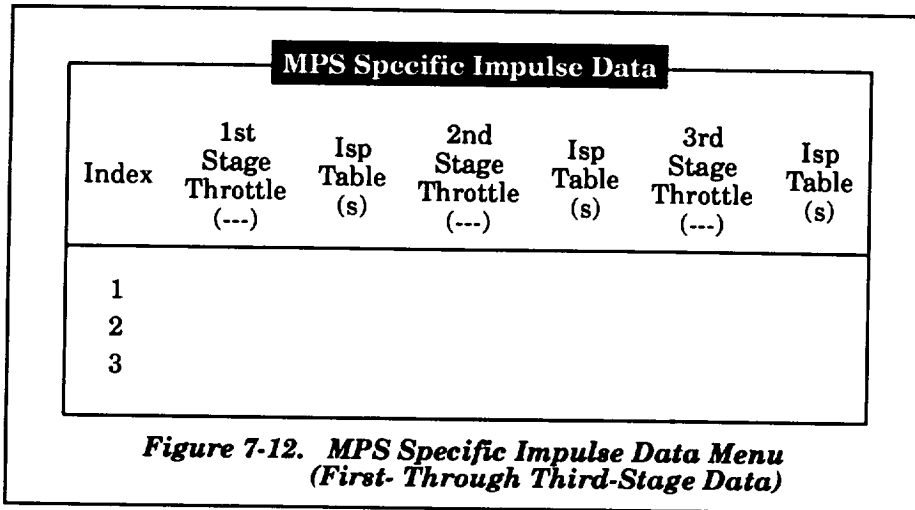


Table 7-7. MPS Specific Impulse Data

Parameter	Description	Units
Throttle Level	Throttle level history	---
Isp Table	MPS specific impulse	s

7.2.6 Constants

Parameters associated with MPS constants are defined in this subsection. **Figure 7-14** provides a display of the parameters, and **Table 7-8** provides the definitions of the parameters under this subsection. As shown in **Figure 7-14**, data is displayed with to the right of the parameter names.

Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

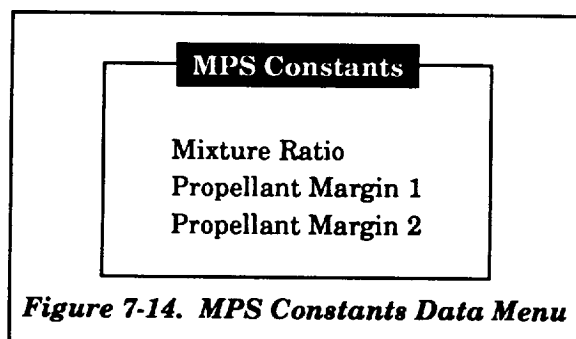
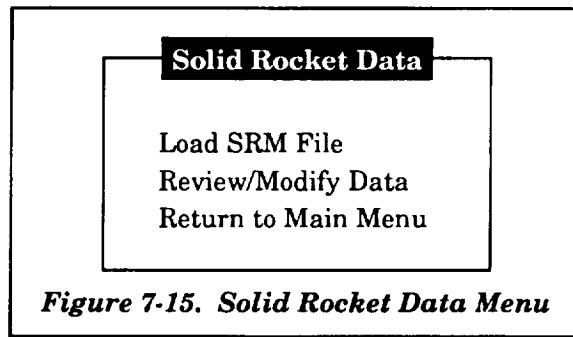


Table 7-8. MPS Constants Data

Parameter	Description	Units
Mixture Ratio	MPS mixture ratio of LH2 to LOX propellant	---
Propellant Margin 1	MPS propellant margin remaining when using the propellant termination option	lb
Propellant Margin 2	MPS propellant margin remaining when using the propellant termination option	lb

7.3 SOLID ROCKET MOTORS

If the "Solid Rocket Motors" item is selected in the propulsion system submenu, the submenu shown in **Figure 7-15** is displayed. SRM data input is stored on a separate file; therefore, the user is required to load the appropriate file. The data on this file can be reviewed and/or modified by use of the input tables under the "Review/Modify Data" item of the submenu. If SRM data are not read from a file, zero values will be displayed on the input tables. The user is returned to this submenu after exiting the selected item. To return to the "Propulsion Data" submenu, the user must select the "Return to Previous Menu" item. Upon exiting, the user is asked if the data are to be stored or not. If it is to be stored, the user can either store the new data under the existing file name or a new file name. The following subsections describe the submenu items.



7.3.1 Load SRM File

Input files for the SRM data are stored with a ".SRM" extension. System routines are used to search the user-defined directory for files that have the ".SRM" extension. After finding the files, the software displays the file names so that the user can select the appropriate file. The selection is made by moving the cursor, via the Arrow Keys, to the selected file and pressing the Return Key.

If no files are found during the search, the user will be prompted **"There are no files with that extension! Look for another extension? (y/n)."** If the user responds with a "Y" or "y", an additional prompt **"enter ext"** will be displayed asking the user to define the new three-character extension. The user may also define a different resident directory. A new search will take place after this. If the user responds with a "N" or "n", the search is terminated and no data are loaded.

7.3.2 Review/Modify Data

Propulsion parameters associated with SRMs are defined in this subsection. **Figure 7-16** provides a display of the parameters, and **Table 7-9** provides the definitions of the parameters under this subsection. As shown in **Figure 7-16**, a matrix of data is displayed with the columns representing the parameters and the rows representing the indices of the tables (maximum of 600 data items per table). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the large number of data items, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

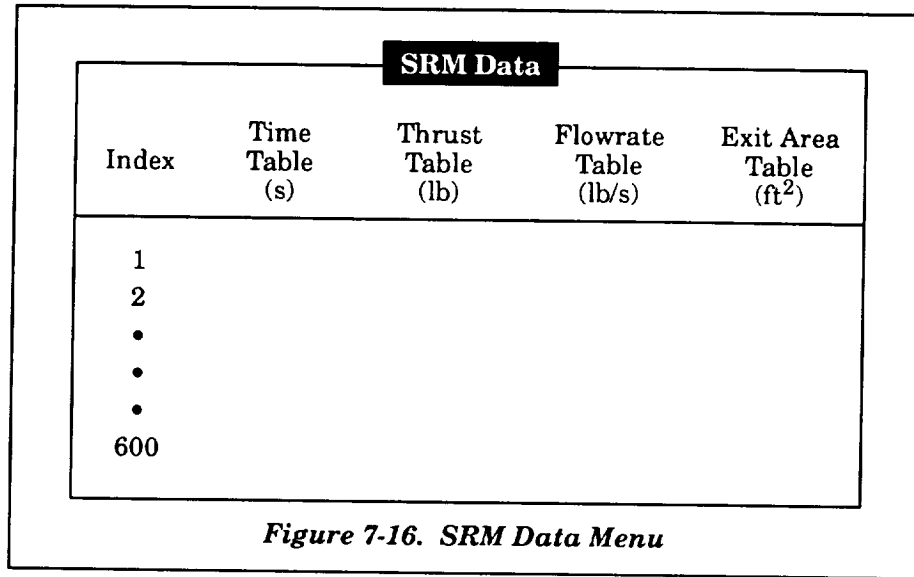


Table 7-9. SRM Propulsion Data

Parameter	Description	Units
Time Table	Time from lift-off	s
Thrust Table	Vacuum thrust of single engine	lb
Flowrate Table	Vacuum propellant flowrate	lb/s
Exit Area Table	Exit area of SRM nozzle	ft ²

7.4 LIQUID BOOST MODULE

Propulsion parameters associated with a LBM propulsion system are defined in this subsection. **Figure 7-17** provides a display of the parameters, and **Table 7-10** provides the definitions of the parameters under this subsection. As shown in **Figure 7-17**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 30 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the large number of data items, the user can utilize the scrolling feature to review and/or modify the data. To exit the window to the "Propulsion Data" submenu, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

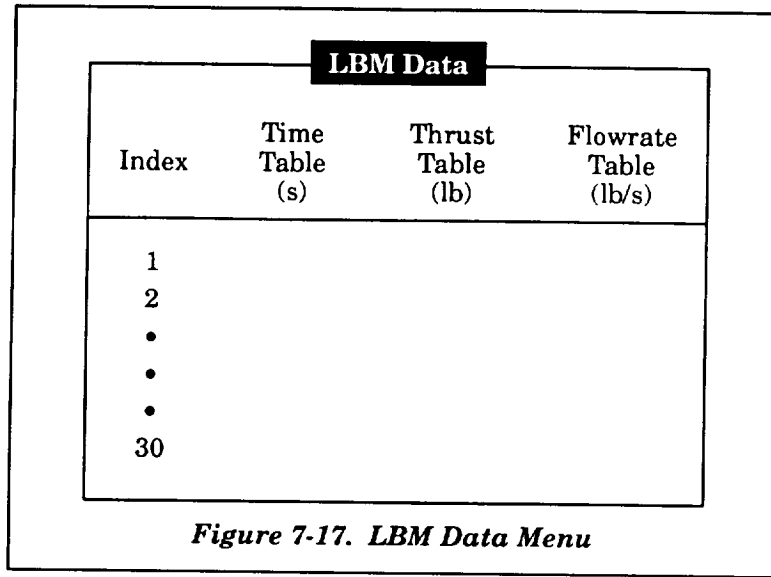


Table 7-10. LBM Propulsion Data

Parameter	Description	Units
Time Table	Time from lift-off	s
Thrust Table	Vacuum thrust of LBM system	lb
Flowrate Table	Vacuum flowrate of LBM system	lb/s

7.5 ORBIT MANEUVER AND ROCKET CONTROL SYSTEMS

Propulsion parameters associated with OMS and RCS propulsion systems are defined in this subsection. **Figure 7-18** provides a display of the parameters, and **Table 7-11** provides the definitions of the parameters under this section. As shown in **Figure 7-18**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 15 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window to the "Propulsion Data" submenu, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

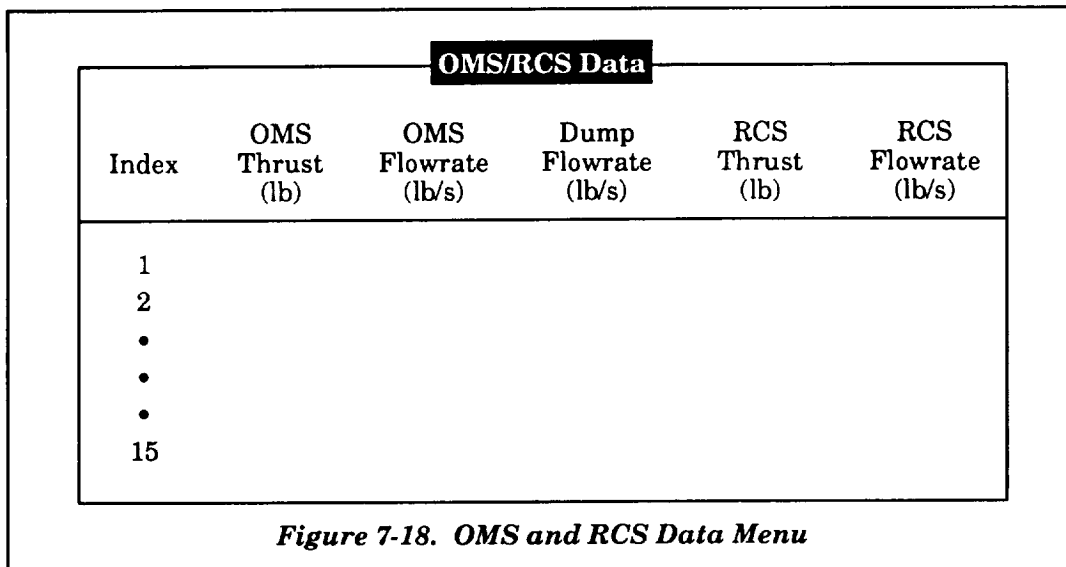
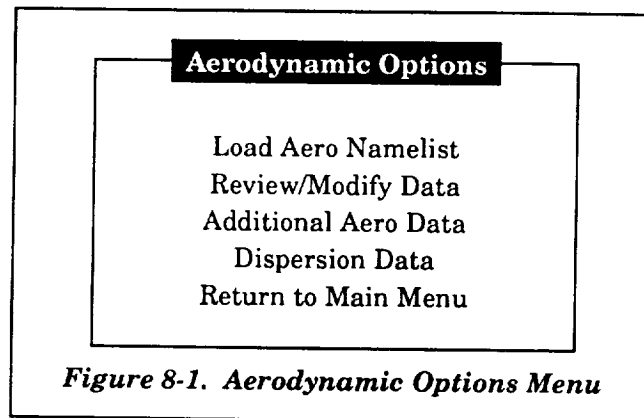


Table 7-11. OMS and RCS Propulsion Data

Parameter	Description	Units
OMS Thrust	OMS vacuum thrust	lb
OMS Flowrate	OMS vacuum propellant flowrate	lb/s
Dump Flowrate	Flowrate of total propellant dumped through the OMS/RCS interconnect system	lb/s
RCS Thrust	RCS vacuum thrust	lb
RCS Flowrate	RCS vacuum propellant flowrate	lb/s

8. AERODYNAMIC DATA

If the user selects the "Aerodynamic Data" item in the main menu, the submenu shown in *Figure 8-1* is displayed. This submenu defines the types of aerodynamic related data available to the user. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and presses the Return Key. The items in the submenu are discussed in the next paragraphs.



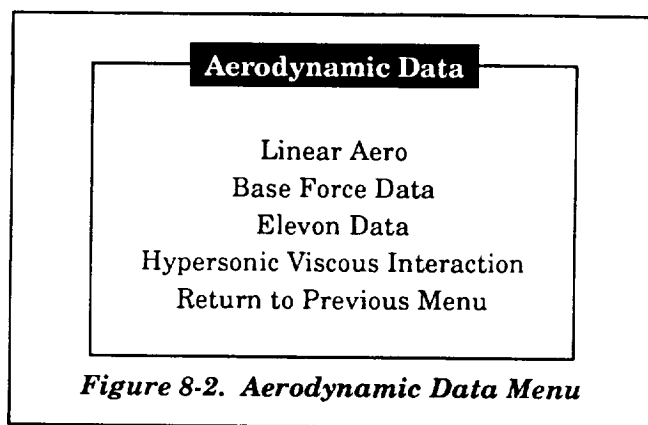
8.1 LOAD AERO NAMELIST

Although the MASTRE Program allows the simulation of both nonlinear and linear aerodynamic data, the User Interface Program is used to review and/or modify the linear aerodynamic data only. Therefore, the input files that are loaded here relate to the linear aerodynamics. The nonlinear aerodynamic data uses a different file and is defined in the execution command file (see Section 17). Input files for the linear aerodynamic data are stored with an ".ANL" extension. System routines are used to search the user-defined directory for files that have the ".ANL" extension. After finding the files, the software displays the file names such that the user can select the appropriate file. The selection is made by moving the cursor, via the Arrow Keys, to the selected file and pressing the Return Key.

If no files are found during the search, the user will be prompted "**There are no files with that extension! Look for another extension? (y/n)**". If the user responds with a "Y" or "y", an additional prompt "**enter ext**" will be displayed asking the user to define the new three-character extension. The user may also select another resident directory. A new search will take place after this. If the user responds with a "N" or "n", the search is terminated and no data are loaded.

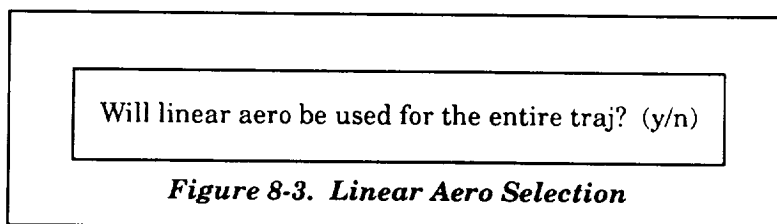
8.2 REVIEW/MODIFY DATA

Selecting the "Review/Modify Data" item of the "Aerodynamics Options" submenu results in the submenu shown in *Figure 8-2*. The items of this submenu provide the different types of aerodynamic data available. The user selects from this submenu by moving the cursor with the up and down Arrow Keys and pressing the Return Key. Upon exiting from the selected item, the user is returned to this submenu. To exit this submenu to the "Aerodynamic Options" submenu, the user must select the "Return to Previous Menu" item.



8.2.1 Linear Aerodynamic Data

Parameters associated with linear aerodynamic data are defined in this subsection. The first display the user sees after selecting "Linear Aero" is the question shown in *Figure 8-3*. A "yes" answer to this question means that the linear aerodynamics defined in this subsection will be used in the entire trajectory. A "no" answer indicates that nonlinear aerodynamics will be used for the first stage, and the linear aerodynamics defined in this subsection will be used in the upper stages. The nonlinear aerodynamics, which are primarily used when simulating the Space Shuttle, use data from a data base file that is defined in the user's command file (see Section 17).



After answering the question, the top window in *Figure 8-4* is displayed. *Figure 8-4* shows the two windows used to display the aerodynamic parameters, and *Table 8-1* provides the definitions

of the parameters under this subsection. The values of aerodynamic data parameters are based on the aerodynamic input files defined under Subsection 8.1; therefore, these files must be loaded previously. Otherwise, zero values will be displayed. As shown in **Figure 8-4**, a matrix of data for each window is displayed with the columns representing the aerodynamic parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user by using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit each window, the user presses the Return Key.

Linear Aero Data

Index	Mach Number Table (---)	CAo Table (---)	CAalp Table (/deg)	CNo Table (---)	CNalp Table (/deg)	Cmo Table (---)	Cmalp Table (/deg)
1							
2							
•							
•							
•							
25							

Linear Aero Data

Index	Mach Number Table (---)	CYo Table (---)	CYbeta Table (/deg)	Cno Table (---)	Cnbeta Table (/deg)	Clo Table (---)	Clbeta Table (/deg)
1							
2							
•							
•							
•							
25							

Figure 8-4. Linear Aerodynamic Data Menu

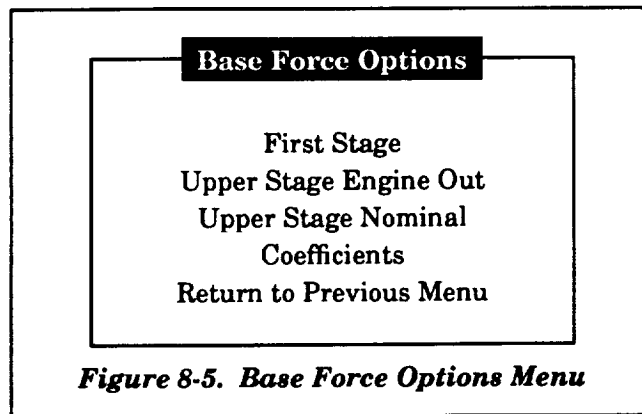
Table 8-1. Linear Aerodynamic Data

Parameter	Description	Units
Mach Number Table	Mach number independent table	---
CAo Table	Axial force coefficient at zero AOA	---
CAalp Table	Axial force slope coefficient with respect to AOA	/deg
CNo Table	Normal force coefficient at zero AOA	---
CNalp Table	Normal force slope coefficient with respect to AOA	/deg
Cmo Table	Pitching moment coefficient at zero AOA	---
Cmalp Table	Pitching moment slope coefficient with respect to AOA	/deg
CYo Table	Side force coefficient at zero sideslip angle	--
CYbeta Table	Side force slope coefficient with respect to sideslip angle	/deg
Cno Table	Yawing moment coefficient at zero sideslip angle	---
Cnbeta Table	Yawing moment slope coefficient with respect to sideslip angle	/deg
Clo Table	Rolling moment coefficient at zero sideslip angle	---
Clbeta Table	Rolling moment slope coefficient with respect to sideslip angle	/deg

If the user wishes to either delete or add a data item row, the user should place the cursor, via the Arrow Keys, over any element of the desired row. Using the Remove Key, the selected row will be deleted and all subsequent rows will be moved up. Using the Insert Here Key, the selected row will move down along with subsequent rows. The selected row will display zero values, which can be modified by the user. Since the same independent Mach table is used for all aerodynamic coefficients, if a row is deleted or added in one of the displays, the other display will reflect the same change.

8.2.2 Base Force Data

Selecting the "Base Force Data" item of the "Aerodynamics Data" submenu results in the submenu shown in **Figure 8-5**. The items of this submenu provide the different types of base force data available. The user selects from this submenu by moving the cursor with the up and down Arrow Keys and pressing the Return Key. Upon exiting from the selected items, the user is returned to this submenu. To exit this submenu to the "Aerodynamic Data" submenu, the user must select the "Return to Previous Menu" item.



8.2.2.1 First-Stage Base Force Data

Parameters associated with first-stage base force data are defined in this subsection. **Figure 8-6** provides a display of the parameters, and **Table 8-2** provides the definitions of the parameters under this subsection. As shown in **Figure 8-6**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 50 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Base Force Data					
First Stage Nominal Index	Altitude Table (ft)	Axial Table (lb)	Normal Table (lb)	Pitch Mom Table (ft-lb)	Ref Dyn Table (psf)
1					
2					
•					
•					
•					
50					

Figure 8-6. First-Stage Base Force Data Menu

Table 8-2. First-Stage Base Force Data

Parameter	Description	Units
Altitude Table	Altitude independent table	ft
Axial Table	Base force axial force	lb
Normal Table	Base force normal force	lb
Pitch Mom Table	Pitching moment due to base force	ft-lb
Ref Dyn Table	Reference dynamic pressure	psf

8.2.2.2 Upper-Stage Engine-Out Base Force Data

Parameters associated with upper-stage engine-out base force data are defined in this subsection. **Figure 8-7** provides a display of the parameters, and **Table 8-3** provides the definitions of the parameters under this subsection. As shown in **Figure 8-7**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 50 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Base Force Data				
Upper Stage Engine-Out Index	Altitude Table (ft)	Axial Table (lb)	Normal Table (lb)	Pitch Mom Table (ft-lb)
1				
2				
•				
•				
•				
50				

Figure 8-7. Upper-Stage Engine-Out Base Force Data Menu

Table 8-3. Upper-Stage Engine-Out Base Force Data

Parameter	Description	Units
Altitude Table	Altitude independent table	ft
Axial Table	Base force axial force	lb
Normal Table	Base force normal force	lb
Pitch Mom Table	Pitching moment due to base force	ft-lb

8.2.2.3 Upper-Stage Nominal Base Force Data

Parameters associated with upper-stage nominal base force data are defined in this subsection. **Figure 8-8** provides a display of the parameters, and **Table 8-4** provides the definitions of the parameters under this subsection. As shown in **Figure 8-8**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 50 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Base Force Data				
Upper Stage Nominal Index	Altitude Table (ft)	Axial Table (lb)	Normal Table (lb)	Pitch Mom Table (ft-lb)
1				
2				
•				
•				
•				
50				

Figure 8-8. Upper-Stage Nominal Base Force Data Menu

Table 8-4. Upper-Stage Nominal Base Force Data

Parameter	Description	Units
Altitude Table	Altitude independent table	ft
Axial Table	Base force axial force	lb
Normal Table	Base force normal force	lb
Pitch Mom Table	Pitching moment due to base force	ft-lb

8.2.2.4 Base Force Coefficients Tables

Parameters associated with base force coefficients data are defined in this subsection. **Figure 8-9** provides a display of the parameters, and **Table 8-5** provides the definitions of the parameters under this subsection. As shown in **Figure 8-9**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 50 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Base Force Data					
Index	Altitude Table (ft)	Alp Coeff Table (/rad)	Betta Coeff Table (/rad)	Throt Coeff Table (---)	Throt Slope Table (---)
1					
2					
•					
•					
•					
50					

Figure 8-9. Base Force Coefficients Menu

Table 8-5. Base Force Coefficients Data

Parameter	Description	Units
Altitude Table	Altitude independent table	ft
Alp Coeff Table	Coefficient used with angle of attack	/rad
Beta Coeff Table	Coefficient used with sideslip angle	/rad
Throt Coeff Table	Coefficient used with throttle	---
Throt Slope Table	Slope coefficient used with throttle	---

8.2.3 Elevon Data

Aerodynamic parameters associated with elevon data are defined in this subsection. **Figure 8-10** provides a display of the parameters, and **Table 8-6** provides the definitions of the parameters under this subsection. As shown in **Figure 8-10**, a matrix of data is displayed with the columns representing the elevon parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Elevon Data						
Index	Rel Vel Table (ft/s)	Inbd Def Sch 6 (deg)	Outbd Def Sch 6 (deg)	Mach Number Table (---)	Inbd Def Table (deg)	Outbd Def Table (deg)
1						
2						
•						
•						
•						
25						

Figure 8-10. Elevon Data Menu

Table 8-6. Elevon Data

Parameter	Description	Units
Rel Vel Table	Earth-fixed relative velocity independent table for Schedule 6 inboard and outboard deflection angles	ft/s
Inbd Def Sch 6	Inboard deflection angle based on Shuttle control Schedule 6	deg
Outbd Def Sch 6	Outboard deflection angle based on Shuttle control Schedule 6	deg
Mach Number Table	Mach number independent table for inboard and outboard deflection angles	---
Inbd Def Table	Active inboard deflection angle	deg
Outbd Def Table	Active outboard deflection angle	deg

8.2.4 Hypersonic Viscous Interaction Data

Aerodynamic parameters associated with hypersonic viscous interaction data are defined in this subsection. **Figure 8-11** provides the three displays of the parameters, and **Table 8-7** provides the definitions of the parameters under this subsection. As shown in **Figure 8-11**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 10 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit each window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Viscous Interaction Data

Index	Mach Number Table (---)	Ca Cont Const (---)	Ca Cont Slope (/deg)	Ca Cont Acc (/deg ²)	Ca Mole Const (---)	Ca Mole Slope (/deg)	Ca Mole Acc (/deg ²)
1							
2							
•							
•							
•							
10							

Viscous Interaction Data

Index	Mach Number Table (---)	Cn Cont Const (---)	Cn Cont Slope (/deg)	Cn Cont Acc (/deg ²)	Cn Mole Const (---)	Cn Mole Slope (/deg)	Cn Mole Acc (/deg ²)
1							
2							
•							
•							
•							
10							

Viscous Interaction Data

Index	Mach Number Table (---)	Cm Cont Const (---)	Cm Cont Slope (/deg)	Cm Cont Acc (/deg ²)	Cm Mole Const (---)	Cm Mole Slope (/deg)	Cm Mole Acc (/deg ²)
1							
2							
•							
•							
•							
10							

Figure 8-11. Viscous Interaction Data Menu

Table 8-7. Hypersonic Viscous Interaction Data

Parameter	Description	Units
Mach Number Table	Mach number	---
Ca Cont Const	Continuum flow axial force constant coefficient	---
Ca Cont Slope	Continuum flow axial force slope coefficient	---
Ca Cont Acc	Continuum flow axial force acceleration coefficient	/deg ²
Ca Mole Const	Free molecular flow axial force constant coefficient	---
Ca Mole Slope	Free molecular flow axial force slope coefficient	/deg
Ca Mole Acc	Free molecular flow axial force acceleration coefficient	/deg ²
Cn Cont Const	Continuum flow normal force constant coefficient	---
Cn Cont Slope	Continuum flow normal force slope coefficient	/deg
Cn Cont Acc	Continuum flow normal force acceleration coefficient	/deg ²
Cn Mole Const	Free molecular flow normal force constant coefficient	---
Cn Mole Slope	Free molecular flow normal force slope coefficient	/deg
Cn Mole Acc	Free molecular flow normal force acceleration coefficient	/deg ²
Cm Cont Const	Continuum flow pitching moment constant coefficient	---
Cm Cont Slope	Continuum flow pitching moment slope coefficient	/deg
Cm Cont Acc	Continuum flow pitching moment acceleration coefficient	/deg ²
Cm Mole Const	Free molecular flow pitching moment constant coefficient	---
Cm Mole Slope	Free molecular flow pitching moment slope coefficient	/deg
Cm Mole Acc	Free molecular flow pitching moment acceleration coefficient	/deg ²

8.3 ADDITIONAL AERO DATA

Parameters associated with additional aerodynamic data are defined in this subsection. **Figure 8-12** provides a display of the parameters, and **Table 8-8** provides the definitions of the parameters under this section. As shown in **Figure 8-12**, data is displayed with the columns representing the parameters. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

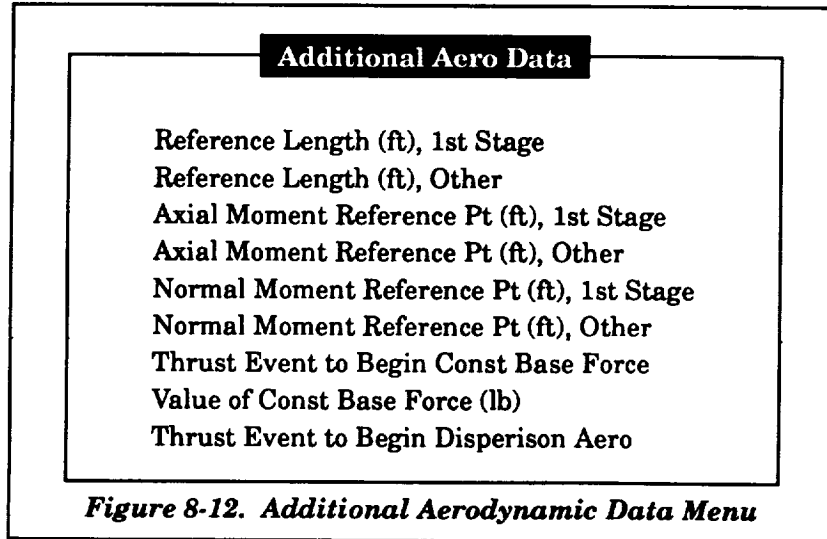


Table 8-8. Additional Aerodynamic Data

Parameter	Description	Units
Reference Length - 1st Stage	Aerodynamic reference length for first stage	ft
Reference Length - Other	Aerodynamic reference length for upper stages	ft
Axial Moment Reference Pt. - 1st Stage	Aerodynamic axial moment reference point for first stage	ft
Axial Moment Reference Pt. - Other	Aerodynamic axial moment reference point for upper stages	ft
Normal Moment Reference Pt. - 1st Stage	Aerodynamic normal moment reference point for first stage	ft
Normal Moment Reference Pt. - Other	Aerodynamic normal moment reference point for upper stages	ft
Thrust Event to Begin Const Base Force	Index of thrust event to begin constant base force	---
Value of Const Base Force	Value of constant base force	lb
Thrust Event to Begin Dispersion Aero	Index of thrust event to begin use of dispersion aerodynamics	---

8.4 DISPERSION DATA

Parameters associated with aerodynamic dispersion data are defined in this subsection. *Figure 8-13* provides a display of the parameters, and *Table 8-9* provides the definitions of the

parameters under this section. As shown in **Figure 8-13**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Aero Dispersion Data						
Index	Mach Number Table (---)	Delta Ca Table (---)	Delta Cn Table (---)	Delta cm Table (---)	Altitude Table (ft)	Delta Fab Table (lb)
1						
2						
•						
•						
•						
25						

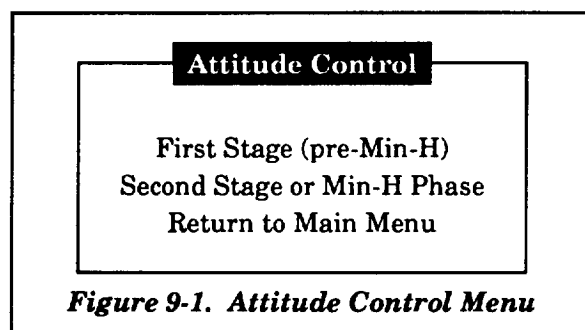
Figure 8-13. Aerodynamic Dispersion Data Menu

Table 8-9. Aerodynamic Dispersion Data

Parameter	Description	Units
Mach Number Table	Mach number independent table for aerodynamic dispersion coefficients	---
Delta Ca Table	Incremental value of axial force coefficient	---
Delta Cn Table	Incremental value of normal force coefficient	---
Delta Cm Table	Incremental value of pitching moment coefficient	---
Altitude Table	Altitude independent table for base force dispersion table	ft
Delta Fab Table	Incremental axial base force	lb

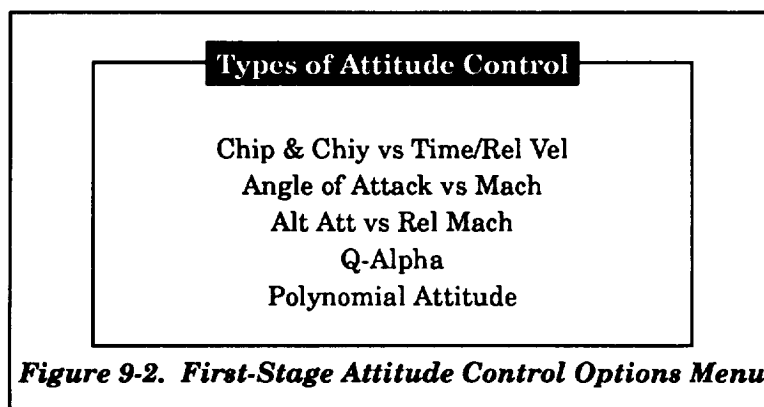
9. ATTITUDE CONTROL

If the user selects the "Attitude Control" item in the main menu, the submenu shown in **Figure 9-1** is displayed. This submenu requires the user to select either the first stage (or pre-min-H attitude control) or the upper stage (or the min-H phase). The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the submenu are discussed in the next subsections.



9.1 FIRST STAGE (PRE-MIN-H)

If the "First Stage (pre Min-H)" item is selected on the "Attitude Control" submenu, the submenu shown in **Figure 9-2** is displayed. This submenu displays the various attitude options that are available for the first stage or pre min-H attitude control. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The following paragraphs define how the user reviews and/or modifies the attitude control options.



9.1.1 Time or Relative Velocity Dependent Pitch and Yaw Attitude

If the "chip & chiy vs time/rel vel" item is selected from the "Types of Attitude Control" submenu, the user is requested to define the independent parameter through the selection of time or relative velocity from the submenu shown in **Figure 9-3**. The data tables following this submenu, as shown in **Figures 9-4 and 9-5**, display the chosen independent parameter and the attitude angles. **Table 9-1** provides the definitions of the parameters defined in these figures. As shown in **Figures 9-4 and 9-5**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key.

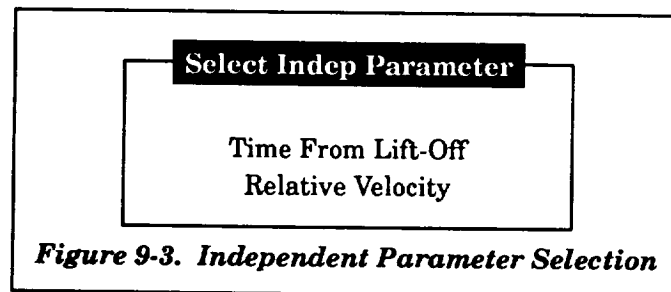


Figure 9-4 is a screenshot of a menu titled "Attitude Control". The menu is enclosed in a rectangular border. Inside the border, there is a table with four columns: "Index", "Time Table (s)", "Chip Table (deg)", and "Chiy Table (deg)". The "Index" column lists the numbers 1, 2, three dots, and 25, indicating a total of 25 data items. The other three columns are empty.

Index	Time Table (s)	Chip Table (deg)	Chiy Table (deg)
1			
2			
•			
•			
•			
25			

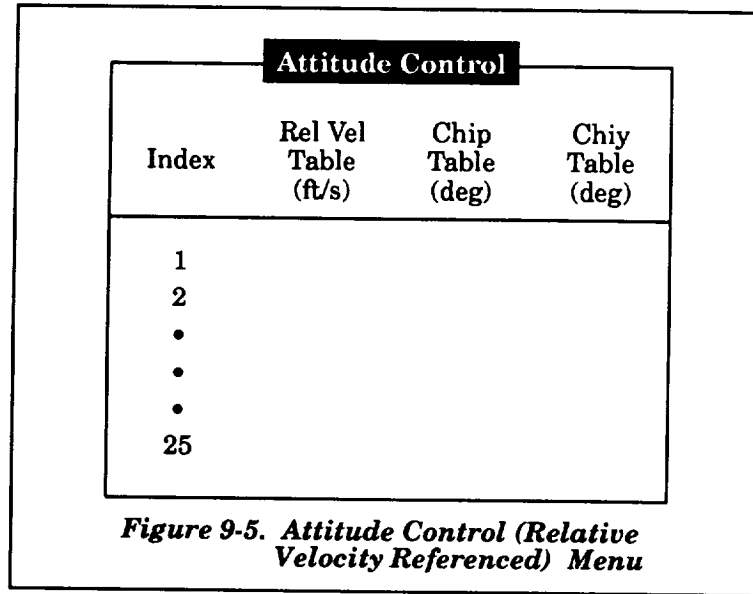


Table 9-1. Time or Relative Velocity Attitude Data

Parameter	Description	Units
Time Table	Time from lift-off independent table	s
Rel Vel Table	Relative velocity independent table	ft/s
Chip Table	Pitch attitude angle in plumblane coordinate system	deg
Chiy Table	Yaw attitude angle in plumblane coordinate system	deg

If the user wishes to either delete or add a data item row, the user should place the cursor, via the Arrow Keys, over any element of the desired row. Using the Remove Key, the selected row will be deleted and all subsequent rows will be moved up. Using the Insert Here Key, the selected row will move down along with the subsequent rows. The selected row will display zero values that can be modified by the user.

9.1.2 AOA and Sideslip Angle Attitude

Attitude parameters associated with AOA and sideslip angle attitude data are defined in this subsection. **Figure 9-6** provides a display of the parameters, and **Table 9-2** provides the definitions of the parameters under this subsection. As shown in **Figure 9-6**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and

pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

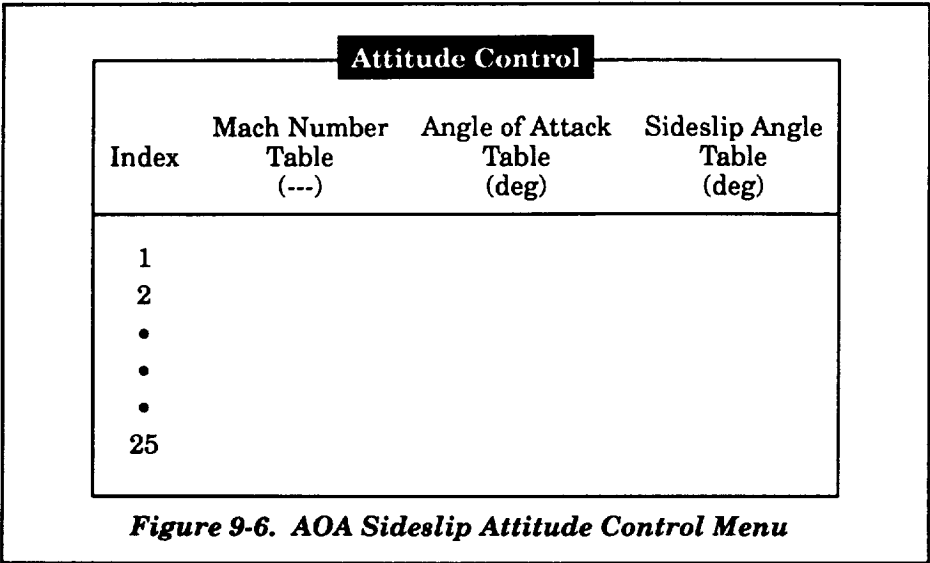


Table 9-2. AOA and Sideslip Angle Attitude Data

Parameter	Description	Units
Mach Number Table	Mach number independent table	---
Angle of Attack Table	Angle of attack	deg
Sideslip Angle Table	Sideslip angle	deg

9.1.3 Alternate Attitude Angles

Attitude parameters associated with alternate attitude control data are defined in this subsection. **Figure 9-7** provides a display of the parameters, and **Table 9-3** provides the definitions of the parameters under this subsection. As shown in **Figure 9-7**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 25 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

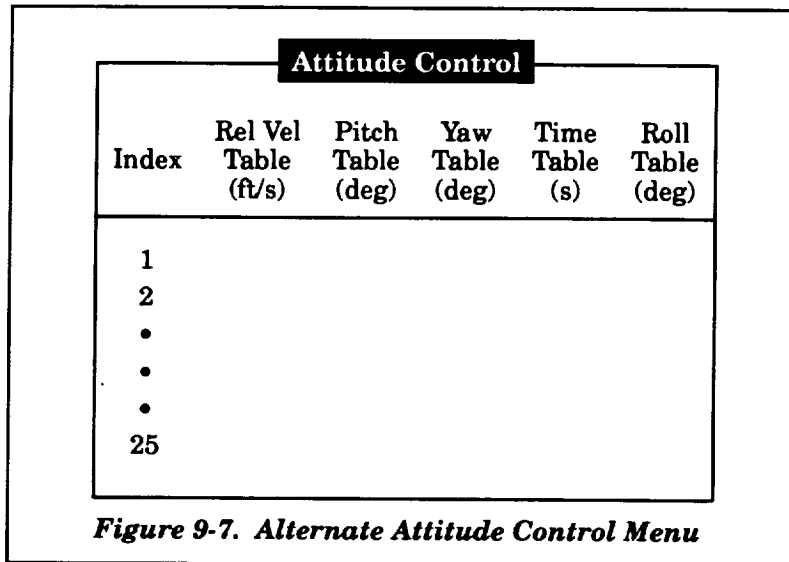


Table 9-3. Alternate Attitude Control Data

Parameter	Description	Units
Rel Vel Table	Relative velocity independent table	ft/s
Pitch Table	Pitch attitude angle	deg
Yaw Table	Yaw attitude angle	deg
Time Table	Time from lift-off independent table	s
Roll Table	Roll attitude angle	deg

9.1.4 Constant Q-Alpha Attitude

The parameter associated with constant Q-alpha attitude data is defined in this subsection. **Figure 9-8** provides a display of the input Q-alpha parameter, and **Table 9-4** provides the definition of the parameter under this subsection. As shown in **Figure 9-8**, data is displayed next to the definition of the parameter. Data can be changed by the user by pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key.

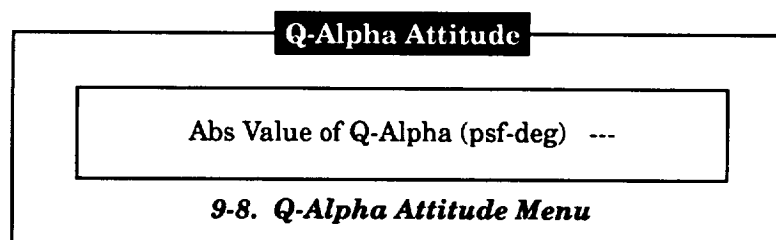


Table 9-4. Q-Alpha Attitude Data

Parameter	Description	Units
Abs Value of Q-alpha	Value of Q-alpha	psf-deg

9.1.5 Polynomial Attitude

Attitude parameters associated with polynomial attitude control data are defined in this subsection. **Figure 9-9** provides a display of the parameters, and **Table 9-5** provides the definitions of the parameters under this subsection. As shown in **Figure 9-9**, data is displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Polynomial Attitude	
Order of First Pitch Polynomial	--
Order of First Yaw Polynomial	--
Order of Second Pitch Polynomial	--
Order of Second Yaw Polynomial	--
Thrust Event to Begin Second Polynomial	--

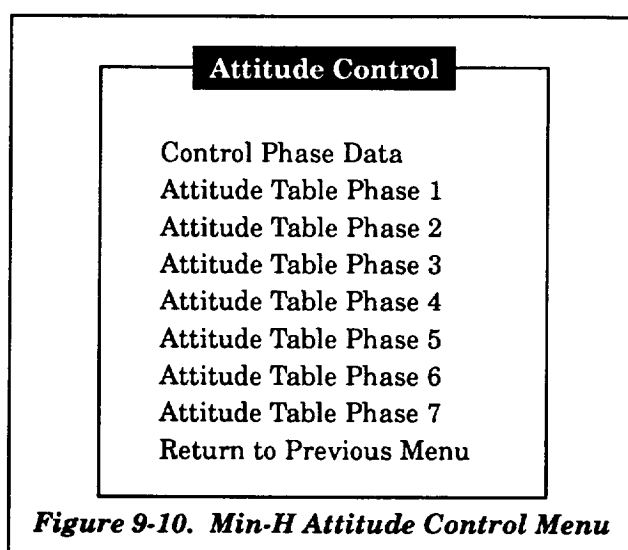
Figure 9-9. Polynomial Attitude Menu

Table 9-5. Polynomial Attitude Data

Parameter	Description	Units
Order of first pitch polynomial	Order of first pitch polynomial equation (used for tilt over maneuver)	---
Order of first yaw polynomial	Order of first yaw polynomial equation (used for tilt over maneuver)	---
Order of second pitch polynomial	Order of second pitch polynomial equation	---
Order of second yaw polynomial	Order of second yaw polynomial equation	---
Thrust event to begin second polynomial	Thrust event index to begin use of second polynomial equations	---

9.2 SECOND STAGE OR MIN-H PHASE

If the "Second Stage or Min-H Phase" item of the "Attitude Control" submenu is selected, the submenu shown in **Figure 9-10** is displayed. This submenu is used to setup the input for the min-H portion of the simulation. The data input under the "Control Phase Data" item of the submenu is used to define the parameters associated with the one to seven available control phases. Once these parameters are defined, the initial angles associated with each control phase are then defined under the "Attitude Table Phase 1" through "Attitude Table Phase 7" items of the submenu. Once the selected item is exited, the user is returned to the submenu. To return to the "Attitude Control" submenu, the "Return to Previous Menu" item should be selected.



9.2.1 Control Phase Data

Attitude parameters associated with min-H phase attitude control data are defined in this subsection. **Figure 9-11** provides a display of the parameters, and **Table 9-6** provides the definitions of the parameters under this subsection. As shown in **Figure 9-11**, data are displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

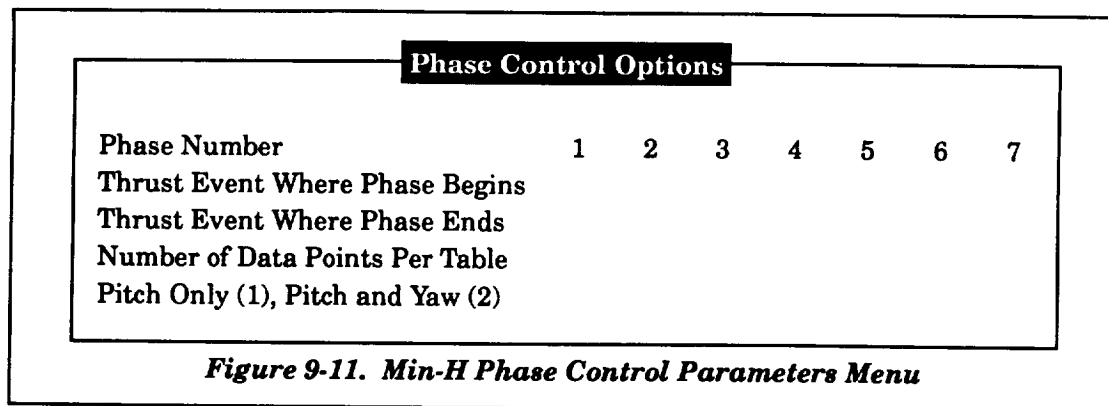


Table 9-6. Min-H Control Phase Data

Parameter	Description	Units
Thrust event where phase begins	Index of thrust event where min-H attitude phase begins	---
Thrust event where phase ends	Index of thrust event where min-H attitude phase ends	---
Number of data points per table	Number of data points per min-H attitude phase	---
Pitch only (1), pitch and yaw (2)	Attitude angle selection option per phase; 1 - pitch attitude only, 2 - pitch and yaw attitude	---

9.2.2 Attitude Table Data

Attitude angle and time parameters associated with min-H attitude control table data are defined in this subsection. **Figure 9-12** provides a generic display of the parameters associated with the seven attitude phases, and **Table 9-7** provides the definitions of the parameters under this subsection. As shown in **Figure 9-12**, a matrix of data is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 30 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are available on this data table.

Attitude Phase No i			
Index	Time Table (s)	Chip Table (deg)	Chiy Table (deg)
1			
2			
•			
•			
•			
30			

Figure 9-12. Min-H Attitude Control Table Menu

Table 9-7. Min-H Attitude Angle Data

Parameter	Description	Units
Time Table	Time from lift-off	s
Chip Table	Pitch attitude angle Plumblin coordinate system	deg
Chiy Table	Yaw attitude angle Plumblin coordinate system	deg

10. MASS PROPERTIES

If the user selects the "Mass Properties" item in the main menu, the submenu shown in **Figure 10-1** is displayed. This submenu allows the user to choose the manner in which mass properties will be calculated in the MASTRE Program. The first option uses the tabular data that defines axial and normal CG as a function of weight overboard. The second option uses inputs generated by separate mass properties program to allow a dynamic calculation of axial and normal CG. The user interface program for the mass properties program is discussed in Appendix A.

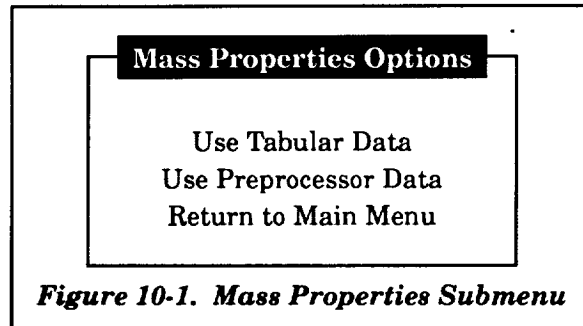


Figure 10-1. Mass Properties Submenu

The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key.

Parameters associated with the mass properties tabular data are defined in this section. **Figure 10-2** provides a display of the parameters while, and **Table 10-1** provides the definitions of the parameters. A matrix of data, as shown in **Figure 10-2**, is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 15 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key.

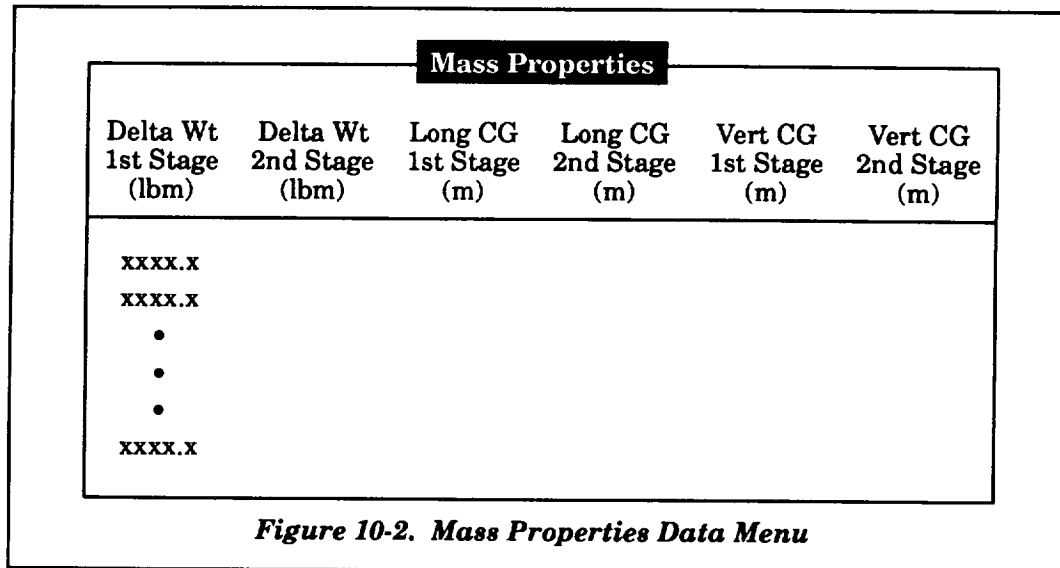


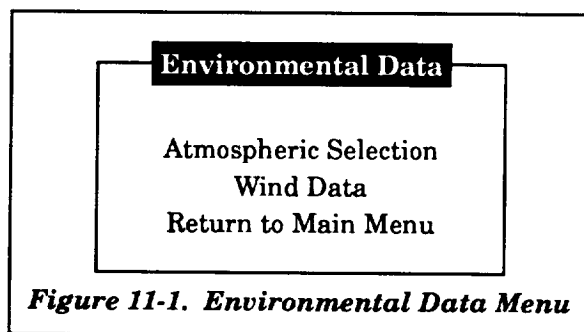
Table 10-1. Mass Properties Data

Parameter	Description	Units
Delta Wt. 1st Stage	First stage weight overboard independent for CG tables	lb
Delta Wt. 2nd Stage	Second stage weight overboard independent for CG tables	lb
Long CG 1st Stage	First stage longitudinal CG	ft
Long CG 2nd Stage	Second stage longitudinal CG	ft
Vert CG 1st Stage	First stage vertical CG	ft
Vert CG 2nd Stage	Second stage vertical CG	ft

If the user wishes to either delete or add a data item row, the user should place the cursor, via the Arrow Keys, over any element of the desired row. Using the Remove Key, the selected row will be deleted and all subsequent rows will be moved up. Using the Insert Here Key, the selected row will move down along with the subsequent rows. The selected row will display zero values that can be modified by the user.

11. ENVIRONMENTAL DATA

If the user selects the "Environmental Data" item in the main menu, the submenu shown in *Figure 11-1* is displayed. This submenu allows the user to select the atmospheric and wind models to be used in the MASTRE simulation. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the submenu are discussed in the next subsections.



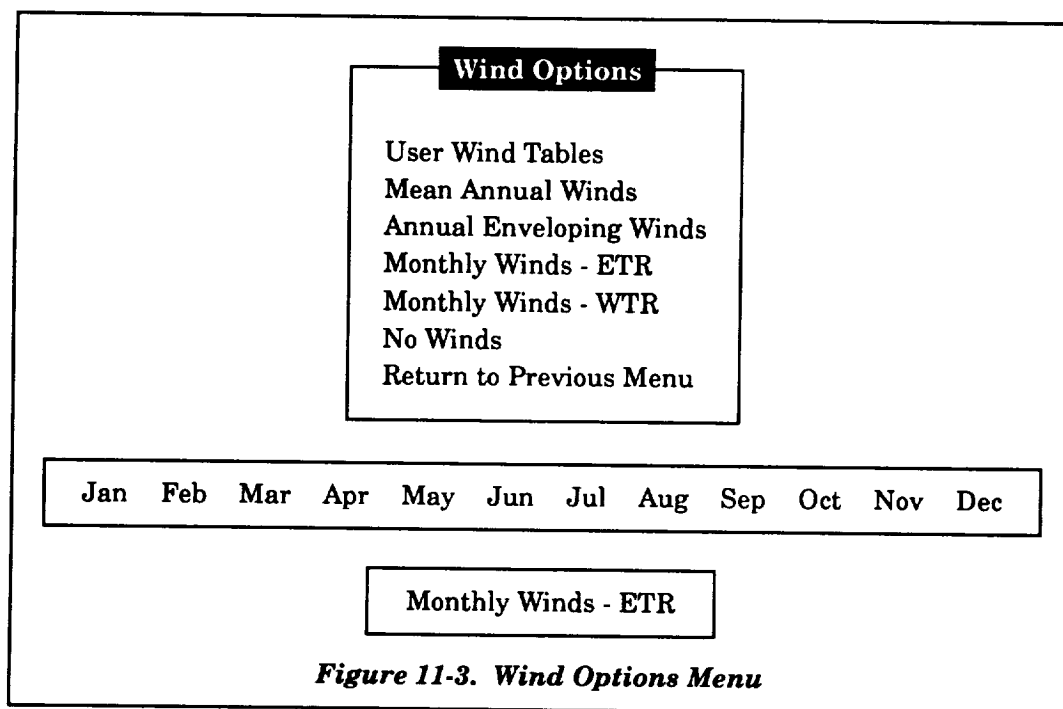
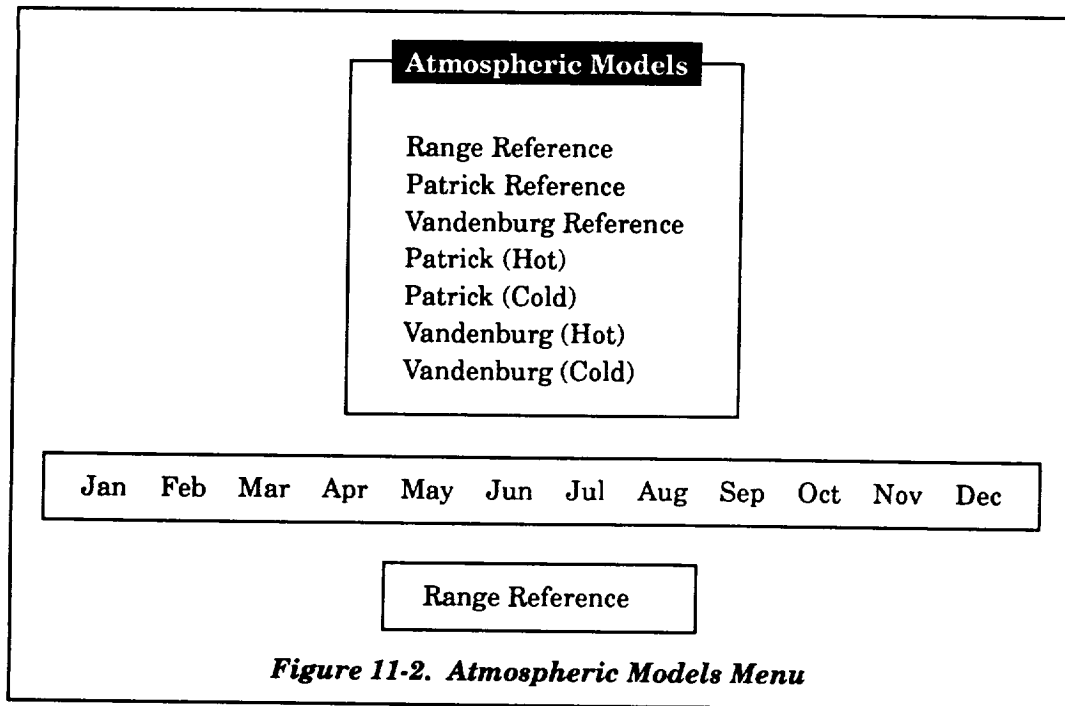
11.1 ATMOSPHERIC SELECTION

The names of the seven atmospheric models shown in *Figure 11-2* are displayed when the user selects the "Atmospheric Selection" item of the "Environmental Data" submenu. The cursor designation when this submenu appears indicates the current selection made in the MASTRE input file. The user selects from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired item and pressing the Return Key. If the "Range Reference" item is selected, the user is also required to select the reference month from the bar shown in *Figure 11-2*.

Regardless of the selection from the "Atmospheric Selection" submenu, the name of the selected atmospheric model will appear in the lower portion of the window, as shown in *Figure 11-2*.

11.2 WIND DATA

The names of the five wind models shown in *Figure 11-3* are displayed as the "Wind Options" submenu when the user selects the "Wind Data" item of the "Environmental Data" submenu. The cursor designation when this submenu appears indicates the current selection made in the MASTRE input file.



If the "User Wind Tables" item is selected from the "Wind Options" submenu, the data tables shown in **Figure 11-4** are displayed. **Table 11-1** defines the parameters associated with this submenu. A matrix of data, as shown in **Figure 11-4**, is displayed with the columns representing the parameters and the rows representing each of the data items (maximum of 100 data items). Data can be changed by the user using the up, down, left, and right Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. Due to the number of data items exceeding the window size, the user can utilize the scrolling feature to review and/or modify the data. To exit the window, the user presses the Return Key.

User Wind Data			
Index	Altitude Table (ft)	Speed Table (ft/s)	Azimuth Table (deg)
1			
2			
•			
•			
•			
100			

Figure 11-4. User Wind Data Menu

Table 11-1. User Wind Data

Parameter	Description	Units
Altitude Table	Altitude independent table	ft
Speed Table	Wind speed	ft/s
Azimuth Table	Wind direction measured clockwise from North	deg

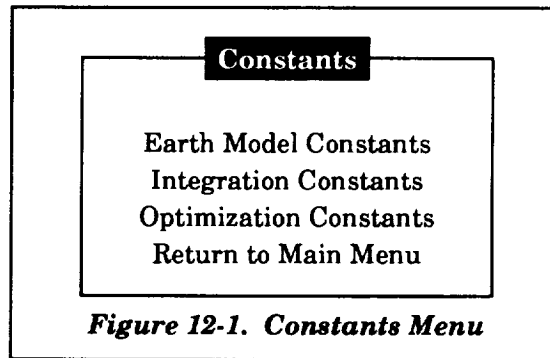
If the user wishes to either delete or add a data item row, the user should place the cursor, via the Arrow Keys, over any element of the desired row. Using the Remove Key, the selected row will be deleted and all subsequent rows will be moved up. Using the Insert Here Key, the selected row will move down along with the subsequent rows. The selected row will display zero values which can be modified by the user.

If either the "Monthly Winds - ETR" or "Monthly Winds - WTR" items are chosen from the "Wind Options" submenu, the user must also select the desired month from the bar shown in **Figure 11-3**.

Regardless of the selection from the "Wind Options" submenu, the name of the selected wind model will appear in the lower portion of the window, as shown in **Figure 11-3**. After each selection is exited, the user is returned to the "Wind Options" submenu. To return to the "Environmental Data" submenu, the user must select the "Return to Previous Menu" item and press the Return Key.

12. CONSTANTS

If the user selects the "Constants" item in the main menu, the submenu shown in **Figure 12-1** is displayed. This submenu allows the user to select the Earth model, integration, and optimization constants that are used in the simulation. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the sub menu are discussed in the next subsection.



12.1 EARTH MODEL CONSTANTS

Parameters associated with Earth model constant data are defined in this subsection. **Figure 12-2** provides a display of the parameters, and **Table 12-1** provides the definitions of the parameters under this subsection. As shown in **Figure 12-2**, data are displayed next to the parameter definitions. Data are read only and cannot be changed by the user. To exit the window, the user presses the Return Key.

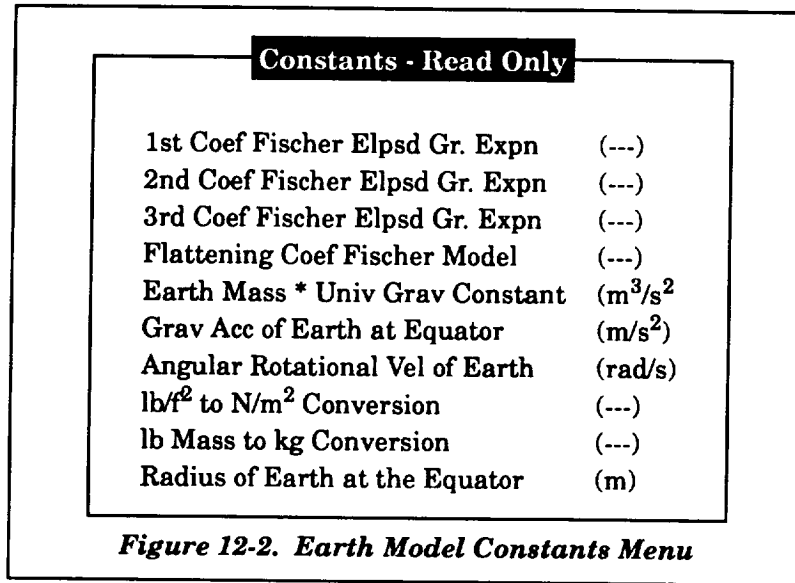


Table 12-1. Earth Model Constants Data

Parameter	Description	Units
1st Coef Fischer Elpsd Gr. Expn	First coefficient in the Fischer ellipsoid gravitational expansion	---
2nd Coef Fischer Elpsd Gr. Expn	Second coefficient in the Fischer ellipsoid gravitational expansion	---
3rd Coef Fischer Elpsd Gr. Expn	Third coefficient in the Fischer ellipsoid gravitational expansion	---
Flattening Coef Fischer Model	Flattening coefficient of the Fischer Model	---
Earth Mass * Univ Grav Constant	Product of the universal gravitational constant and the mass of the earth	m ³ /s ²
Grav Acc of Earth at Equator	Gravitational acceleration of the earth at the equator	m/s ²
Angular Rotational Vel of Earth	Angular rotational velocity of the earth	rad/s
lb/ft ² to N/m ² Conversion	Conversion from lb/ft ² to N/m ²	---
lb Mass to kg Conversion	Conversion from pounds mass to kilograms	---
Radius of Earth at the Equator	Radius of the earth at the equator	m

12.2 INTEGRATION CONSTANTS

Parameters associated with integration constant data are defined in this subsection. **Figure 12-3** provides a display of the parameters, and **Table 12-2** provides the definitions of the parameters under this subsection. As shown in **Figure 12-3**, data are displayed next to the parameter definitions. Additional help to the user is provided, as shown in **Figure 12-3**, when either the forward or backward integration method item of the submenu is selected. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Integration Constants

Integration Method	-forward
Integration Method	- backward
Integration Order of Differences	- forward
	- backward
Min Step Size	- forward
	- backward
Smallest Value of Dep Var for Step	- forward
	- backward
Upper Limit for Step Size Control	- forward
	- backward

Integration Types

1 - Variable Step Adams-Moulton

2 - Fixed Step Runge-Kutta

3 - Fixed Step Adams Predictor Only

Figure 12-3. Integration Constants Menu

Table 12-2. Integration Constants Data

Parameter	Description	Units
Integration Method	Integration method indicator 1 - variable step size Adams-Moulton 2 - fixed step Runge-Kutta 3 - fixed step Adams-Predictor only	---
Integration Order of Differences	Order of differences used in the integration scheme when using variable step size integration	---
Min Step Size	Minimum step size for integration	
Smallest Value of Dep Var for Step	Smallest value of dependent variable for step size control	---
Upper Limit for Step Size Control	Upper bound on integration step size control algorithm	---

12.3 OPTIMIZATION CONSTANTS

Parameters associated with optimization constant data are defined in this subsection. **Figure 12-4** provides a display of the parameters, and **Table 12-3** provides the definitions of the parameters under this subsection. As shown in **Figure 12-4**, data are displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Optimization Constants	
Maximize (1) or Minimize (-1)	1.0
Constraint Step Size	0.25
Optimality Step Size	0.80
Convergence Tolerance	0.005
Increment for Pitch Att Partial	0.1
Increment for Yaw Att Partial	0.1

Figure 12-4. Optimization Constants Menu

Table 12-3. Optimization Constants Data

Parameter	Description	Units
Maximize (1) or Minimize (-1)	This parameter declares that the payoff function will be either maximized (with a value of 1) or minimized (with a value of -1)	---
Constraint Step Size	Decimal fraction of constraint error to remove on first iteration (if initial guesses are known to be good, a value of 1 will speed convergence)	---
Optimality Step Size	Decimal fraction of optimization step used during the optimization process	---
Convergence Tolerance	Convergence tolerance on the value of the normalized total derivatives of the payoff with respect to the parameters (output as "NEW PCON")	---
Increment for Pitch Attitude Partial	Value of incremental pitch attitude angle used to determine forward difference partial derivative for first-stage pitch attitude parameters (non-min-H)	deg
Increment for Yaw Attitude Partial	Value of incremental yaw attitude angle used to determine forward difference partial derivative for first-stage yaw attitude parameters (non-min-H)	deg

13. OPERATIONAL OPTIONS

If the user selects the "Operational Options" item in the main menu, the submenu shown in **Figure 13-1** is displayed. This submenu allows the user to select operational options that are used in the simulation. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the submenu are discussed in the next subsections.

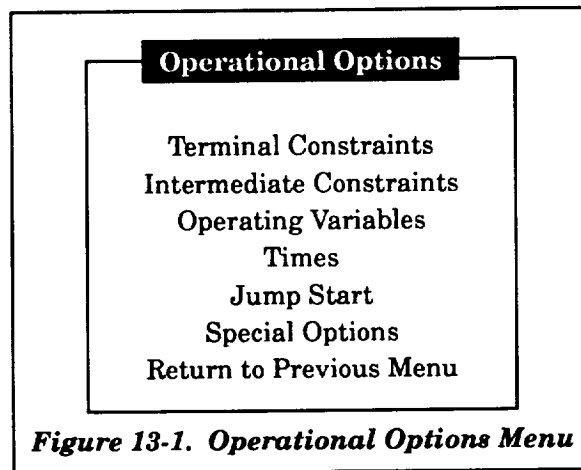


Figure 13-1. Operational Options Menu

13.1 **TERMINAL CONSTRAINTS**

Selecting the "Terminal Constraints" item on the "Operational Options" submenu allows the user to select and quantify the terminal constraints that are applied at the end of the forward trajectory. The display shown in **Figure 13-2** is used to define the payoff function that is to be maximized or minimized as well as the terminal conditions that are to be satisfied. The types of parameters are specified by the user placing constraint codes under the "Constraint Code" header of **Figure 13-2**. The codes are obtained from the "Constraint Code Reference" column of **Figure 13-2**. The first parameter under the "Constraint Code" header is considered the payoff, or optimization, function. The values of the other parameters are defined next to the constraint codes under the "Constraint Value" header. Data are changed for either the codes or values by moving the cursor (via the up, down, right, and left Arrow Keys), pressing the Select Key keying in the desired data, and pressing the Return Key. To exit this window, the user presses the Return Key.

Constraint Code Reference	<==Constraint Code	Constraint Value
1 - Cutoff Weight (lb)	1	<-- Optimization
2 - Inertial Velocity (m/s)	2	xxxx.xx
3 - Inertial Flight Path Angle (deg)	3	x.xxxxx
4 - Radius (m)	4	xxxxxxxxx.
5 - Altitude (Oblate Earth) (m)	10	xx.xxxx
6 - Not Used at This Time	-	-
7 - Earth Fixed Velocity (m/s)	-	-
8 - Earth Rel Heading Angle (deg)	-	-
9 - Earth Rel Flt-Path Angle (deg)	-	-
10 - Inclination (deg)	-	-
11 - Inert Descending Node (deg)		
12 - Not Used at This Time		
13 - Not Used at This Time		
14 - Orbital Velocity (m/s)		
15 - Max Dynamic Pressure (psi)		
16 - Stag Heating Indicator (BTU)	Terminal constraints	
17 - RTLS Term Condition (m/s)	Hit select to change	
18 - RTLS Init Condition (m/s)	Arrow keys to move	
19 - Range from Launch Site (nm)		

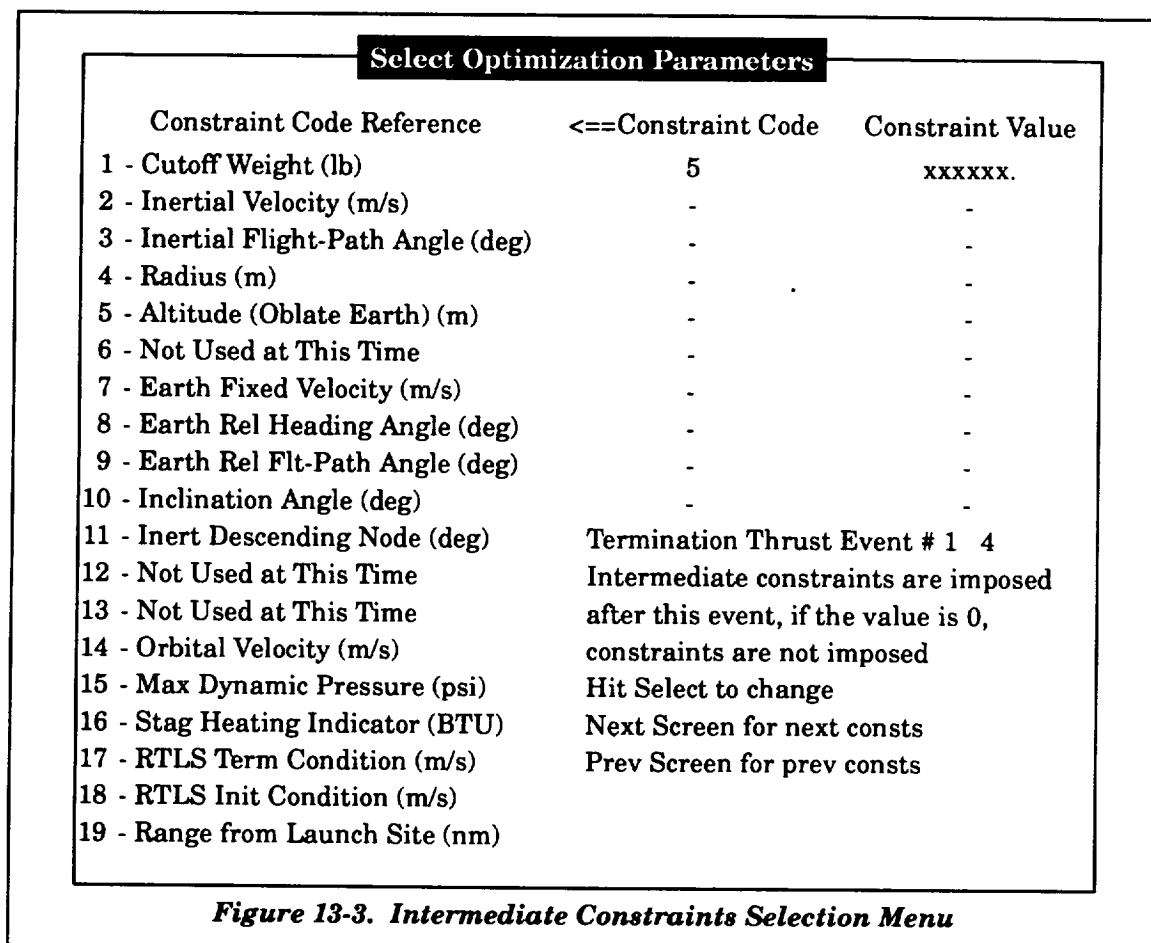
Figure 13-2. Terminal Constraints Selection Menu

13.2 INTERMEDIATE CONSTRAINTS

Selecting the "Intermediate Constraints" item on the "Operational Options" submenu allows the user to select and quantify the intermediate constraints that are applied at the end of specified thrust events during the forward trajectory. The display shown in **Figure 13-3** is used to define the specified thrust event as well as the intermediate conditions that are to be satisfied. The types of parameters are specified by the user placing constraint codes under the "Constraint Code" header of **Figure 13-3**. The codes are obtained from the "Constraint Code Reference" column of **Figure 13-3**. The values of the parameters are defined next to the constraint codes under the "Constraint Value" header.

The user is first requested to define the index number of the thrust event where the intermediate constraint will be imposed. To modify the current value, the user presses the Select Key, keys in the desired index number, and presses the Return Key. Whether modifying the data or not, pressing the Return Key displays the codes and values and moves the cursor to the newly displayed

items. Data are changed for either the codes or values by moving the cursor (via the up, down, right, and left Arrow Keys), pressing the Select Key, keying in the desired data, and pressing the Return Key.



Since there can be up to five intermediate constraints imposed, the user may select either the Next Scrn or Prev Scrn Keys to transfer from one intermediate constraint window to another. The index number of the intermediate constraint window is shown in **Figure 13-3** to the right of the "#" sign. To return to the "Operational Options" submenu, the user presses the Return Key once if the codes and values are displayed and twice if the codes and values are not displayed.

13.3 OPERATING VARIABLES

Parameters associated with operating variable data are defined in this subsection. **Figure 13-4** provides a display of the parameters, and **Table 13-1** provides the definitions of the parameters under this subsection. As shown in **Figure 13-4**, data are displayed next to the parameter definitions. Additional help to the user, as shown in **Figure 13-4**, is displayed when either the

"Printout Option" or "Vehicle Orientation" items of the data are selected. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

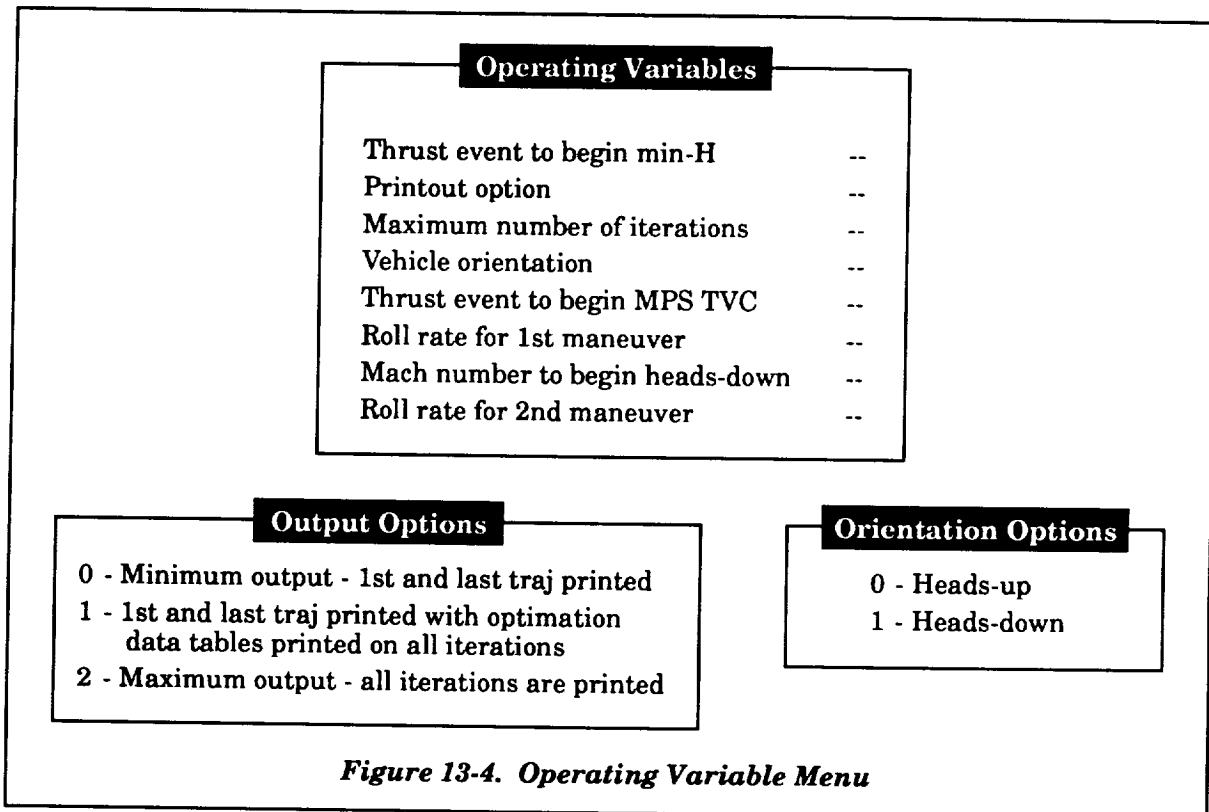


Table 13-1. Operating Variable Constants

Parameter	Description	Units
Thrust Event to Begin min-H	Thrust event to begin first min-H attitude phase	---
Printout Option	Printout option 0 - Minimum output - first and last trajectories printed 1 - First and last trajectories printed with optimization data tables printed on all iterations 2 - Maximum output - all iterations are printed	---
Maximum Number of Iterations	Maximum number of iterations	---
Vehicle Orientation	Vehicle orientation option 0 - heads-up, 1 - heads-down	---
Thrust Event to Begin MPS TVC	Thrust event number of begin MPS thrust vector control (TVC)	---
Roll Rate for 1st Maneuver	Roll rate for 1st-stage roll maneuver	deg/s
Mach Number to Begin Heads-Down	Mach number to begin heads down maneuver	---
Roll Rate for 2nd Maneuver	Roll rate for 2nd roll maneuver during upper stage	deg/s

13.4 TIMES

Parameters associated with time data are defined in this subsection. **Figure 13-5** provides a display of the parameters, and **Table 13-2** provides the definitions of the parameters under this subsection. As shown in **Figure 13-5**, data are displayed next to the parameter definitions. Data can be changed by the user by the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

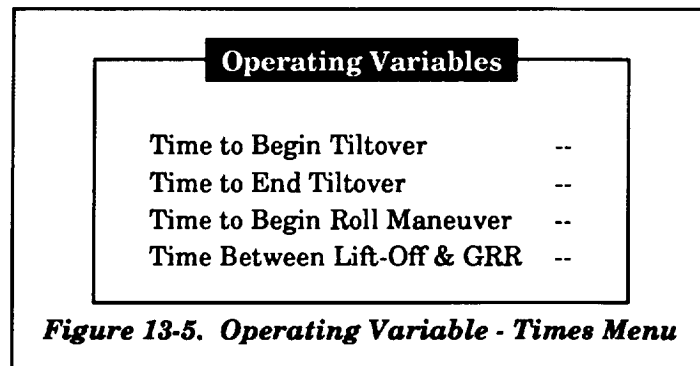
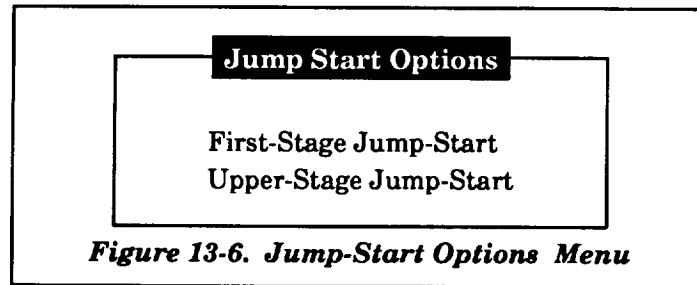


Table 13-2. Time Variables

Parameter	Description	Units
Time to begin tiltover	Time that signifies the end of the lift-off and the beginning of the attitude control program	s
Time to end tiltover	Time that signifies the end of the lift-off phase	s
Time to begin roll maneuver	Time that signifies the beginning of the rolling maneuver, which rolls the tail fin from initial azimuth into the flight plane in a heads-up or heads-down position. Termination of the rolling maneuver is calculated by dividing the roll angle required by the roll rate.	s
Time between lift-off and GRR	Time from ground reference release (GRR) to lift-off. GRR is the point in the countdown at which the launch inertial coordinate system is established.	

13.5 JUMP START

Selecting the "Jump Start" item of the "Operational Options" submenu displays the submenu shown in **Figure 13-6**. This submenu allows the user to select whether first-stage or upper stage jump-start is required. If the user selects the first-stage jump-start, jump-start conditions are stored as an output file (specified in the command file) based on the input times defined on the inputs provided on the first-stage jump-start data table. If the upper-stage jump-start item is selected, the jump-start is activated on the current simulation. The next subsections define the parameters associated with the jump-start options.



13.5.1 First-Stage Jump-Start

Parameters associated with first-stage jump-start data are defined in this subsection. *Figure 13-7* provides a display of the parameters, and *Table 13-3* provides the definitions of the parameters under this subsection. As shown in *Figure 13-7*, data are displayed next to the parameter definitions. Data can be changed by the user by the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Jump Start Variables	
Number of Thrt Evnt to Begin Simulation	1
1st Time to Save State for 1st Stg Jump-Start	--
2nd Time to Save State for 1st Stg Jump-Start	--
3rd Time to Save State for 1st Stg Jump-Start	--
4th Time to Save State for 1st Stg Jump-Start	--
5th Time to Save State for 1st Stg Jump-Start	--

Figure 13-7. Jump-Start Variables Menu

Table 13-3. First-Stage Jump-Start Data

Parameter	Description	Units
Number of Thrust Event to Begin Simulation	Index number of thrust event to begin simulation	---
1st Time to Save State for 1st Stage Jump-Start	First time to save state for first-stage jump-start	s
2nd Time to Save State for 1st Stage Jump-Start	Second time to save state for first-stage jump-start	s
3rd Time to Save State for 1st Stage Jump-start	Third time to save state for first-stage jump-start	s
4th Time to Save State for 1st Stage Jump-Start	Fourth time to save state for first-stage jump-start	s
5th Time to Save State for 1st Stage Jump-Start	Fifth time to save state for first-stage jump-start	s

13.5.2 Upper-Stage Jump-Start

Parameters associated with upper-stage jump-start data are defined in this subsection. **Figure 13-8** provides a display of the parameters, and **Table 13-4** provides the definitions of the parameters under this subsection. As shown in **Figure 13-8**, data are displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

Jump Start Variables

Number of Thrt Evnt to Begin Simulation
w - Velocity Component (ft/s)
u - Velocity Component (ft/s)
v - Position Component (ft/s)
x - Position Component (ft)
y - Position Component (ft)
z - Position Component (ft)
MPS Propellant Mass (lb)
SRM Propellant Mass (lb)
LBM Propellant Mass (lb)
OMS Propellant Mass (lb)
RCS Propellant Mass (lb)
Fixed MPS Propellant Mass (lb)
Stagnation Heating (BTU)
Ideal Velocity (ft/s)
Back Pressure Loss (ft/s)
Gimbal Loss (ft/s)
Gravity Loss (ft/s)
Turning Loss (ft/s)
Aerodynamic Loss (ft/s)
Q penalty Function (psf)
Dump Mass (lb)
Not Used
Not Used
Not Used

Figure 13-8. Upper-Stage Jump-Start Input Menu

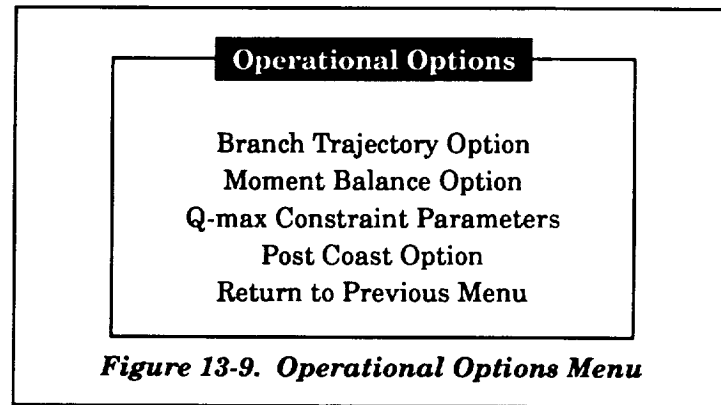
Table 13-4. Upper-Stage Jump-Start Data

Parameter	Description	Units
Number of Thrust Event to Begin Simulation	Number of thrust event to begin simulation (>1 for upper-stage jump-start)	---
w - Velocity Component	x velocity component of inertial plumbline coordinate system	m/s
u - Velocity Component	y velocity component of inertial plumbline coordinate system	m/s
v - Velocity Component	z velocity component of inertial plumbline coordinate system	m/s
x - Position Component	x position component of inertial plumbline coordinate system	m
y - Position Component	y position component of inertial plumbline coordinate system	m
z - Position Component	z position component of inertial plumbline coordinate system	m
MPS Propellant Mass	Propellant mass of MPS	lb
SRM Propellant Mass	Propellant mass of SRM propulsion system	lb
LBM Propellant Mass	Propellant mass of LBM propulsion system	lb
OMS Propellant Mass	Propellant mass of OMS	lb
RCS Propellant Mass	Propellant mass of RCS	lb
Fixed MPS Propellant	Propellant mass of fixed MPS mass	lb
Stagnation Heating	Stagnation heating indicator	BTU/ft ²
Ideal Velocity	Ideal velocity	m/s
Back Pressure Loss	Back pressure loss	m/s
Gimbal Loss	Gimbal loss	m/s
Gravity Loss	Gravity loss	m/s
Turning Loss	Turning loss	m/s
Aerodynamic Loss	Aerodynamic loss	m/s
Q Penalty Function	Dynamic pressure penalty function	psf
Dump Mass	Propellant mass of OMS/RCS interconnect system	lb

13.6 SPECIAL OPTIONS

There are several special options that are available to the user. *Figure 13-9* provides a display of the submenu of the special option topics. The user selects one of these topics by using the

up and down cursor Arrow Keys and pressing the Return Key. The following paragraphs explain the options inputs.



13.6.1 Branch Trajectory Option

Parameters associated with the branch trajectory option data are defined in this subsection. **Figure 13-10** provides a display of the parameters, and **Table 13-5** provides the definitions of the parameters under this subsection. As shown in **Figure 13-10**, data are displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. When moving the cursor, help menus, as shown in **Figure 13-10**, are displayed for each of the data items. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

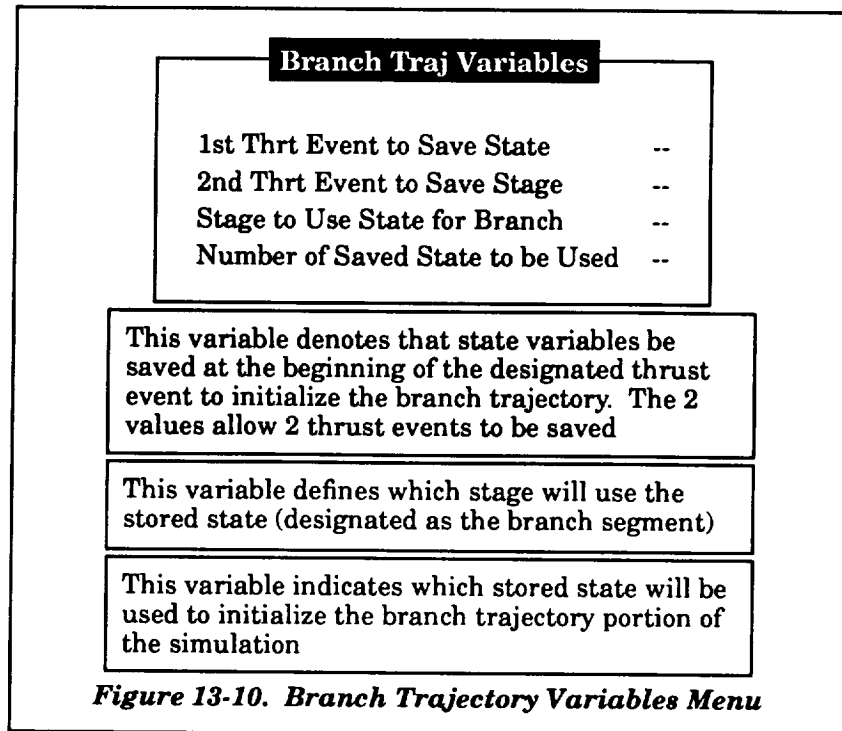
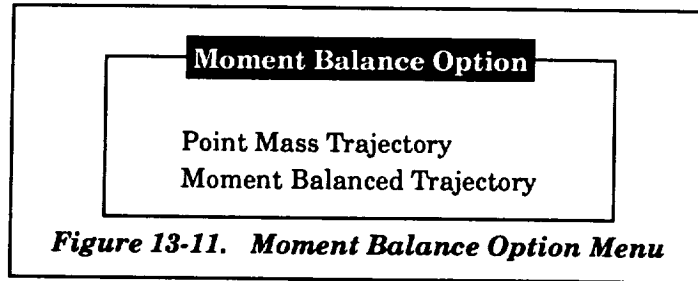


Table 13-5. Branch Trajectory Option Data

Parameter	Description	Units
1st Thrt Event to Save State	Index of thrust event that the state variables at the end of the thrust event will be stored for simulation of a later portion of the branch trajectory	---
2nd Thrt Event to Save State	Index of thrust event that the state variables at the end of the thrust event will be stored for simulation of a later portion of the branch trajectory	---
Stage to Use State for Branch	Index number used to indicate the stage where the stored state will be used for initialization	---
Number of Saved State to be Used	Index defining which stored state will be used (i.e., 1 or 2)	---

13.6.2 MOMENT BALANCE OPTION

The moment balance option allows the user to select whether the engines are considered to be fixed during the simulation or controllable based on zeroing the total aerodynamic and thrust moments. If the user selects this item, the user is asked to select from the menu shown in **Figure 13-11**. The user responds by placing the cursor over the desired option and pressing the Return Key. The user is then returned to the special options submenu.



13.6.3 Q-Max Constraint Parameters

Parameters associated with Q-max constraint parameter data are defined in this subsection (see *Figure 13-12* for Q-max option menu). *Figure 13-13* provides a display of the parameters, and *Table 13-6* provides the definitions of the parameters under this subsection. As shown in *Figure 13-13*, data are displayed next to the parameter definitions. Data can be changed by the user using the up and down Arrow Keys to move the cursor to the desired parameter, pressing the Select Key, keying in the changed value, and pressing the Return Key. To exit the window, the user presses the Return Key. The insert and delete features previously discussed are not used on this data table.

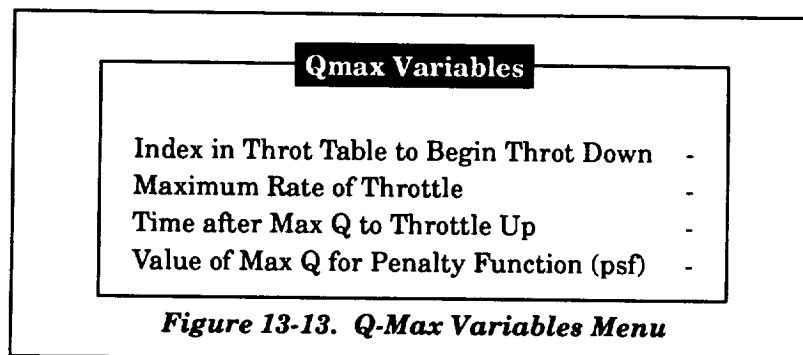
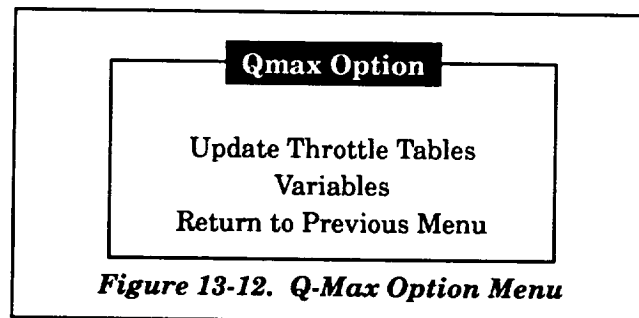


Table 13-6. Q-Max Variable Data

Parameter	Description	Units
Index in throttle table to begin throt down	Index number of MPS throttle table used to indicate where the throttle-down maneuver begins	---
Maximum rate of throttle	Maximum rate of throttle for throttle-up or throttle-down maneuvers	/s
Time after Q-max to throttle up	Time interval after maximum dynamic pressure to throttle-up	s
Value of Q-max for penalty function	Value of maximum dynamic pressure used to calculate penalty function (currently not used)	psf

13.6.4 Post Coast Option

The post coast option allows the simulation to generate a coast trajectory after the last thrust event on the converged trajectory. The display, as shown in **Figure 13-14**, provides the necessary input for this option, which is the index number of the thrust event. The option is activated by a nonzero value for this index number. If this option is used, the user must also supply the time interval for this event under thrust event related data (see Section 4).

Coast Phase

Number of Thro Evnt Used for Coast -

Figure 13-14. Coast Phase Variable Menu

14. OPTIMIZATION DATA

If the user selects the “Optimization Data” item in the main menu, the data table shown in **Figure 14-1** is displayed. This data table allows the user to select the optimization parameters that will be used in the simulation. These parameters have either a value of zero or one. A zero value means that the parameter is not optimized; a value of one means that the parameter will be optimized during the simulation. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection, pressing the Select Key, keying in the desired value, and pressing the Return Key. To exit to the main menu, the user must press the Return Key.

Optimization Parameters

Enter 1 (Active) or 0 (Inactive)

1st Thr Evnt Duration Time	0
2nd Thr Evnt Duration Time	0
3rd Thr Evnt Duration Time	0
4th Thr Evnt Duration Time	0
5th Thr Evnt Duration Time	0
6th Thr Evnt Duration Time	0
7th Thr Evnt Duration Time	0
8th Thr Evnt Duration Time	0
9th Thr Evnt Duration Time	0
10th Thr Evnt Duration Time	0
11th Thr Evnt Duration Time	0
12th Thr Evnt Duration Time	0
13th Thr Evnt Duration Time	0
14th Thr Evnt Duration Time	0
15th Thr Evnt Duration Time	0
Liftoff Weight	0
Launch Azimuth	0
1st Value of Pitch Att Table	0
2nd Value of Pitch Att Table	0
3rd Value of Pitch Att Table	0
4th Value of Pitch Att Table	0
5th Value of Pitch Att Table	0
6th Value of Pitch Att Table	0
7th Value of Pitch Att Table	0
1st Value of Yaw Att Table	0
2nd Value of Yaw Att Table	0
3rd Value of Yaw Att Table	0
4th Value of Yaw Att Table	0
Time to Begin Throttle (Q-max)	0
Time Past Q-max to Throttle Up	0
Value to Ramp Throttle	0

Figure 14-1. Optimization Parameters Menu

15. OUTPUT OPTIONS

If the user selects the "Output Options" item in the main menu, the submenu shown in **Figure 15-1** is displayed. This submenu allows the user to select output options that are used in the simulation. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the submenu are discussed in the next paragraphs.

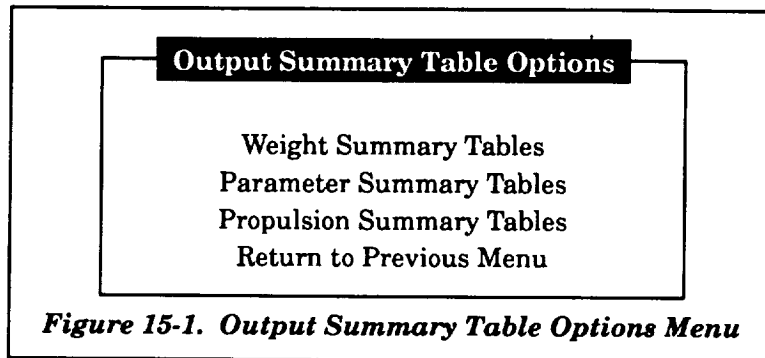


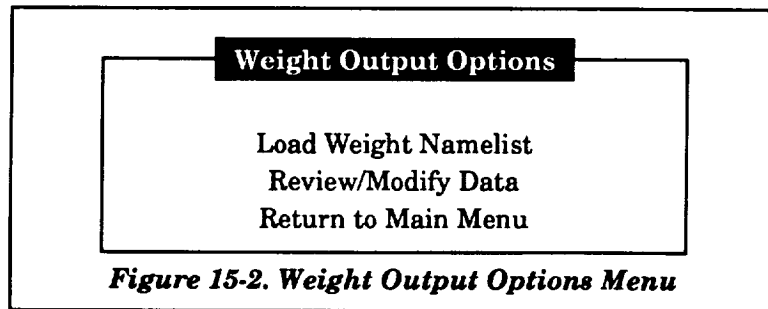
Figure 15-1. Output Summary Table Options Menu

15.1 WEIGHT SUMMARY TABLES

The weight summary tables provide detailed weight breakdowns of the inert weights, burned and residual propellant weights, dry weights, and payload associated with the vehicle that the user is simulating. Therefore, the weights associated with the weight summary tables are dependent on the vehicle system defined when the user first enters the User Interface Program. The weight summary tables are output at the end of the simulation run and provide the user with valuable information concerning the distribution of weight as well as the final payload.

The menu, shown in **Figure 15-2**, displays the options available to the user. Since input for the weight summary tables is provided in a separate Namelist file, the user can either use data from an existing file or build the data table. If the "Load Weight Namelist" options is used, the user is first prompted to define the directory/subdirectory and the file name. A system search is used to find all files with a ".wnl" extension, and the user is required to select one. The selection is done by moving the cursor with the up, down, right, and left Arrow Keys to the desired file name and pressing the Return Key. If no files are found during the search, the user will be prompted **"There are no files with that extension! Look for another extension? (y/n)"**. If the user responds with a "Y" or "y", an additional prompt **"enter ext"** will be displayed asking the user to define the new three character extension. The

user may also define a new directory/subdirectory. A new search will take place after this. If the user responds with a "N" or "n", the search is terminated and no data are loaded and all values are zeroed.



Depending on the system that the user is simulating, the data shown in either **Figure 15-3** for the Multistage Liquid Vehicle System, **Figure 15-4** for the Multistage SRB Vehicle System, or **Figure 15-5** for the Space Shuttle will be displayed if the "Review/Modify Data" selection is made. If a branch trajectory is being simulated, there will be two sets of numerical data that correspond to each data item; otherwise, one set of numerical data will be present. The user can modify these data by using the up, down, right, and left Arrows Keys to move the cursor to the selected data, pressing the Select Key, keying the new data, and pressing the Return Key. To exit, the user presses the Return Key. Upon exiting, the user is asked if the updated data are to be saved. If the answer is yes, the user is prompted to supply a new file name. If the answer is no, the updated data will not be stored. After either response, the user is then returned to the "Output Options" submenu.

- Upper Stage
 - Inert Structure
 - Flight Performance Reserve
 - Delta Velocity reqd (fps)
 - Specific Impulse (sec)
 - Fuel Bias
 - Prop Residuals/Unusables
- Performance Margin
 - Payload
 - Other
- 2nd Stage
 - Stage Inert Weight (less eng)
 - Nonpropulsive Consumables
 - Dry Weight of Engine(s)
 - Prop Residuals/Unusables
 - Flight Performance Reserve
 - Fuel Bias
 - MPS Thrust Buildup
 - Boiloff, Overfill, Drainback
- Shroud
 - Weight separated at MECO
 - Jettison Weight
- 1st Stage
 - Stage Inert Weight (less eng)
 - Dry Weight of Engine(s)
 - Nonpropulsive Consumables
 - Fuel bias
 - Prop Residuals/Unusables
 - MPS Thrust Buildup
 - Boiloff, Overfill, Drainback

Figure 15-3. Multistage Liquid Vehicle Weight Summary Inputs

- Upper Stage - Inert Structure
 - Flight Performance Reserve
 - Delta Velocity reqd (fps)
 - Specific Impulse (sec)
 - Fuel Bias
 - Prop Residuals/Unusables
- Performance Margin - Payload
 - Other
- 2nd Stage - Stage Inert Weight (less eng)
 - Nonpropulsive Consumables
 - Dry Weight of Engine (s)
 - Prop Residuals/Unusables
 - Flight Performance Reserve
 - Fuel Bias
 - MPS Thrust Buildup
 - Boiloff, Overfill, Drainback
- Shroud - Weight separated at MECO
 - Jettison Weight
- 1st Stage - Stage Inert Weight (less eng)
 - Dry Weight of Engine(s)
 - Nonpropulsive Consumables
 - Fuel bias
 - Prop Residuals/Unusables
- Strap-on - Inert Motor Weight (less eng)
 - Dry Weight of Engine(s)
 - Nonpropulsive Consumables
 - Fuel Bias
 - Prop Residuals/Unusables
 - Inerts Consumed (SRM Only)
- MPS - MPS Thrust Buildup
 - Boiloff, Overfill, Drainback

Figure 15-4. Multistage SRB Vehicle Weight Summary Inputs

Mission Kit
 OMS Kit
 Orbiter - Empty
 - Nonpropulsive Consumables
 - RCS Reserves
 - RCS Residuals
 - OMS Propellant (deorbit)
 - OMS Reserves
 - OMS Residuals
 SSME Empty
 Trapped MPS Propellant - Orbiter
 - SSME
 Flight Performance Reserve - Orbiter
 - SSME
 RCS Propellant - ET Separation
 External Tank - Empty
 - Residuals
 Fuel Bias
 Flight Performance Reserve - ET
 Expelled MPS Propellant
 LBM Inert Weight
 SRM Inert Weight
 SRM Residual Propellant
 Inerts Consumed
 SRB Inerts
 MPS Thrust Buildup + SRM Ignition Delay
 Overfill, Drainback, and Boiloff
 Nonpropulsive Consumables

Figure 15-5. Space Shuttle Weight Summary Inputs

15.2 PARAMETER SUMMARY TABLES

Parameter summary tables are optional tables that are printed at the end of the converged trajectory on the FOR021.DAT file. This option provides 14 publishable output tables that show a time history of many of the parameters generated by the MASTRE Program.

Since this is an option to the user, the first display the user sees is a question to determine if the user will use this option (see **Figure 15-6**). If the answer is no, the user is returned to the output options submenu. If the answer is yes, the submenu shown in **Figure 15-7** is displayed. This submenu allows the user to review and modify each of the types of parameters available under each table. The user can modify each parameter by placing the cursor at the parameter and pressing the return key. A scrollable table of all parameter choices is shown in the lower left part of the screen. The user can

now select the parameter by highlighting the selection with the cursor and pressing the return key. If a choice of units is available, a table is shown in the lower right part of the screen. The user highlights the choice and presses the return key. The table is then updated with the new selection. To exit, the user selects "Return to Previous Menu" to return to the output summary tables submenu and selects the "Return to Previous Menu" in the tables submenu to return to the options menu.

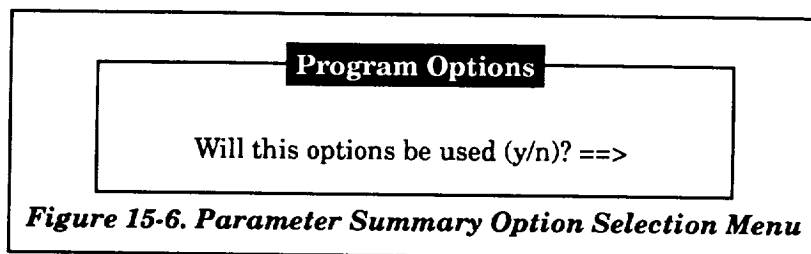


Figure 15-6. Parameter Summary Option Selection Menu

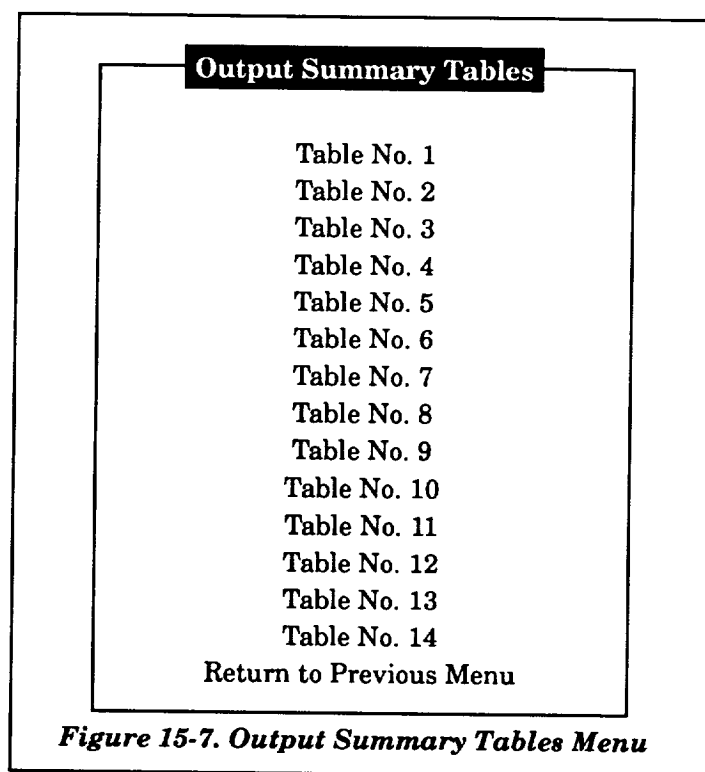


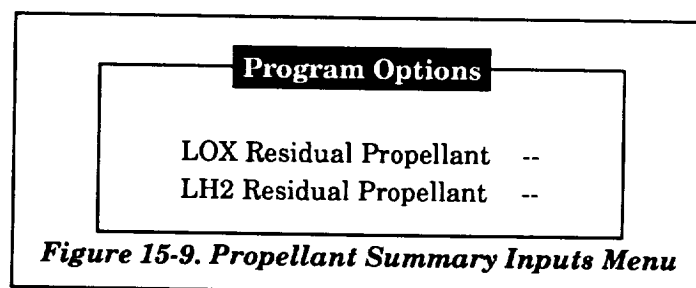
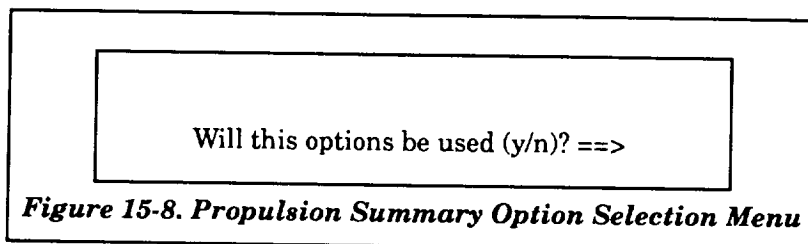
Figure 15-7. Output Summary Tables Menu

15.3 PROPULSION SUMMARY TABLES

Propulsion summary tables are optional tables that are printed at the end of the converged trajectory on the FOR007.DAT file. This option provides one publishable output table that show a time history of propulsion parameters (primarily associated with propellant heights in the tanks) generated

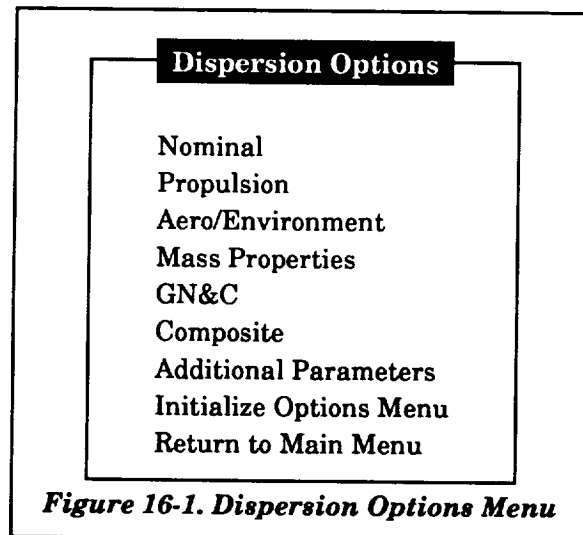
by the MASTRE Program. Using this option requires inputting two additional files that are declared in the command file (see Section 17).

Since this is an option to the user, the first display is a question to determine if the user will use this option (see **Figure 15-8**). If the answer is no, the user is returned to the output options submenu. If the answer is yes, the data table shown in **Figure 15-9** is displayed. This data table shows two variables that must be input. To edit the input data, the user selects the data item with the up and down cursor Arrow Keys, presses the Select Key, keys in the desired data, and presses the Return Key. To exit to the output options submenu, the user presses the Return Key.



16. DISPERSIONS

If the user selects the "Dispersions" item in the main menu, the submenu shown in **Figure 16-1** is displayed. This submenu allows the user to select the dispersion options. The first six items of this submenu define the type of dispersion trajectory that will be simulated, the next item defines additional input parameters that must be included to simulate the dispersion runs, the next item provides a method for initialization of the dispersion output file, and the last item returns the user to the Main Menu. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main Menu" item and press the Return Key. The items in the submenu are discussed in the next paragraphs.



If one of the first six items of the submenu is chosen, a series of windows are displayed. If the "nominal" item is selected, a lower window displays the selection of the nominal item. If any other item of the six items is selected, a window showing the different types of cases under the category selected is displayed. The user, using the up and down cursor Arrow Keys, selects the appropriate choice and presses the Return Key. After the Return Key is pressed, a lower window displays the selection, and another window is used to define whether the run is for a positive or negative dispersion case. The user again makes a selection, and the selection is displayed in the lower window. The user is then returned to the dispersion submenu. To exit to the Main Menu, the user must select the "Return to Main Menu" item of the submenu.

The next subsections discuss the other items in the submenu.

16.1 ADDITIONAL DISPERSION PARAMETERS

When simulating dispersion trajectories, it is important to maintain a common time history between all runs. The purpose of these additional parameters is to provide inputs that will provide a common time history. If the "Additional Parameters" item is selected from the submenu, the data table shown in **Figure 16-2** is displayed. **Table 16-1** provides a definition of these parameters. To edit this data table, the user uses the up and down cursor Arrow Keys to select the data item, presses the Select Key, types in the desired data, and presses the Return Key. To exit to the dispersion submenu, the user presses the Return Key.

Additional Dispersion Inputs

1st step size used for output file	--
2nd step size used for output file	--
Time @ which the 2nd step size starts	--

Figure 16-2. Additional Dispersion Inputs Menu

Table 16-1. Additional Dispersion Parameters

Parameter	Description
1st step size used for output file	Step size used for print out of dispersion output primarily during first stage
2nd step size used for output file	Step size used for print out of dispersion output primarily during upper stages
Time @ which the 2nd step size starts	Time from liftoff to initiate 2nd step size

16.2 FILE OPTIONS

A single output file is used in dispersion studies to provide an output storage medium for the data. After completing the dispersion runs, the generated output file can be used by the RSS Program (see Subsection 2.6.3) to calculate statistical data and to provide plotting output files. When beginning a dispersion study, the user must initialize the output file by using either of the options shown in **Figure 16-3**. (**WARNING: Initialization of the output file after starting the study will erase all previous data from the file.**) The initialization is necessary since the output is a direct access file that has an unique format. As shown in **Figure 16-3**, the user can either create a new file or reinitialize an old file. If a new file is desired, the user is prompted to define a director/subdirectory

and a file name, and the initialization process begins. If an old file is to be reinitialized, the program searches for all files in the current directory with a ".DSP" extension. Once these files are found, the list of files is displayed and the user can select from the list. The selection is made using the up, down, left, and right cursor Arrow Keys to select the desired file name and pressing the Return Key. After the selection is made, the reinitialization process is performed.

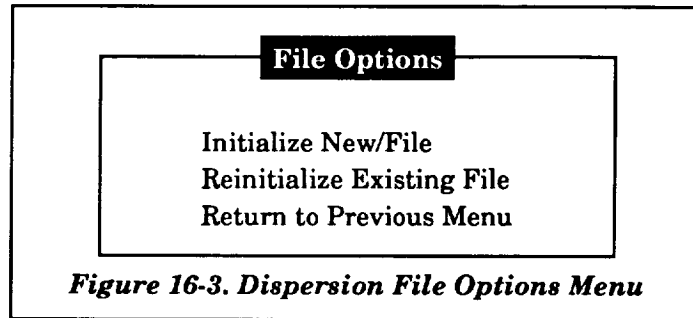
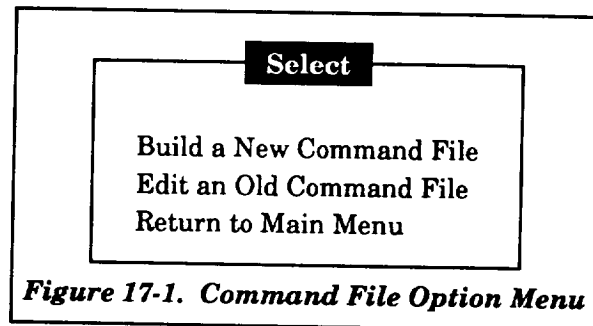


Figure 16-3. Dispersion File Options Menu

If no files are found during the search, the user will be prompted "**There are no files with that extension! Look for another extension? (y/n).**" If the user responds with a "Y" or "y", an additional prompt "**enter ext**" will be displayed asking the user to define the new three-character extension. The user may also define a new directory/subdirectory. A new search will take place after this. If the user responds with a "N" or "n", the search is terminated and the user is returned to the file option submenu.

17. COMMAND FILES

If the user selects the "Command Files" item in the main menu, the submenu shown in *Figure 17-1* is displayed. This submenu allows the user to either build a new command file, edit an old command file, or return to the main menu. The user chooses an item from this submenu by moving the cursor, via the up and down Arrow Keys, to the desired selection and pressing the Return Key. The user is returned to the submenu after exiting the selection. To return to the main menu, the user must select the "Return to Main menu" item and press the Return Key. The items in the submenu are discussed in the next subsections.



17.1 BUILDING A NEW COMMAND FILE

If the user wishes to build a command file, the "Built a new command file" item on the submenu is selected, which results in the display shown in *Figure 17-2*. This display shows three windows: "Select," "Build," and "Data Input." To build a new command file, the user responds in the "Data Input" window, to the requests listed in *Table 17-1*. These requests are used to define the input and output files that are used by the MASTRE Program. When the user responds, the records of the new command file are displayed one-by-one in the "Build" window. The "Data Input" window also provides response information for the user. The user has a choice of responding in either of three ways: the Return Key can be pressed, which defaults to the characters provided within the brackets shown on the request; the Select Key can be pressed and the appropriate file name can be typed in; or the Find Key can be pressed, which searches for all files in the current directory with the same extension, prints the list of files in the "Select" window, and allows the user to pick from this list. If the Find Key is used, the desired file name can be selected by moving the cursor, via the Arrow Keys, to the file name in the "Select" window and pressing the Return Key. The selected file name is then placed in the new command file in the "Build" window. If no files are found during the search, a message is displayed and a blank record is placed in the command file. If this happens, the user must modify the command file record (by using the Select Key) to account for the blank record.

<div style="background-color: black; color: white; padding: 2px 5px; display: inline-block;">SELECT</div>	<div style="background-color: black; color: white; padding: 2px 5px; display: inline-block;">SELECT</div>
	<pre> \$write sys\$output "com file" \$run [mastre.work]mastre yes yes 2 2 no aero15.anl mis2branch.wnl no mis2branch.inl no 1 0 1 </pre>
<div style="background-color: black; color: white; padding: 2px 5px; display: inline-block;">Data Input</div>	
Enter title for this com file [com file] ==> Press=> RETURN for [default]. FIND to select file SELECT to enter data	

Figure 17-2. Build Command File Work Menu

After entering the optional title of the command file, the user will notice that several records are output on the command file as default values (see Subsection 2.6.5 for definitions of these records). If the user wishes to edit these default values, the build process must be complete, the new command file must be saved, and the "Edit an old command file" option must be selected.

If a request has a default value with an asterisk followed by an extension, the user can either use the Select Key to type in the file name or use the Find Key to activate a search for files with the same extension. The Find Key allows the user to select the desired file name from the list of available files.

For consistency checking, input flags are checked if a particular file is requested. If the internal input flags (from the input file defined at the initiation of the User Interface Program) are not consistent with the files being defined in the command file (i.e., an output file that has not been requested), one of three events will occur. Either an error message is displayed to the user and nothing is done, the input flags are changed to reflect the command file, or the input flag is changed based on additional information supplied by the user. If the user tries to insert either a first-stage jump-start

input or output file into the command file and the input does not include provisions for a first-stage jump-start (i.e., a lift-off time that is nonzero and corresponding to a time on the input file or the omission of a first-stage jump-start time used to generate the output file) an error message will be displayed and no action will be taken. If the user includes an alternate mass properties file or LOX and LH2 input files and internal flags have not been set, these flags will be set. If the dispersion file is included and the user has not provided a dispersion flag (i.e., the IVAR variable discussed in Subsection 2.6.3), the program will allow the user to define this input flag through a series of menus in the "Select" window. These menus, which define the types of dispersion cases, are shown in **Figure 17-3**. If the dispersion file is included, the user must also supply additional information that is provided in Subsection 16.1, as well as initializing the file as discussed in Subsection 16.2.

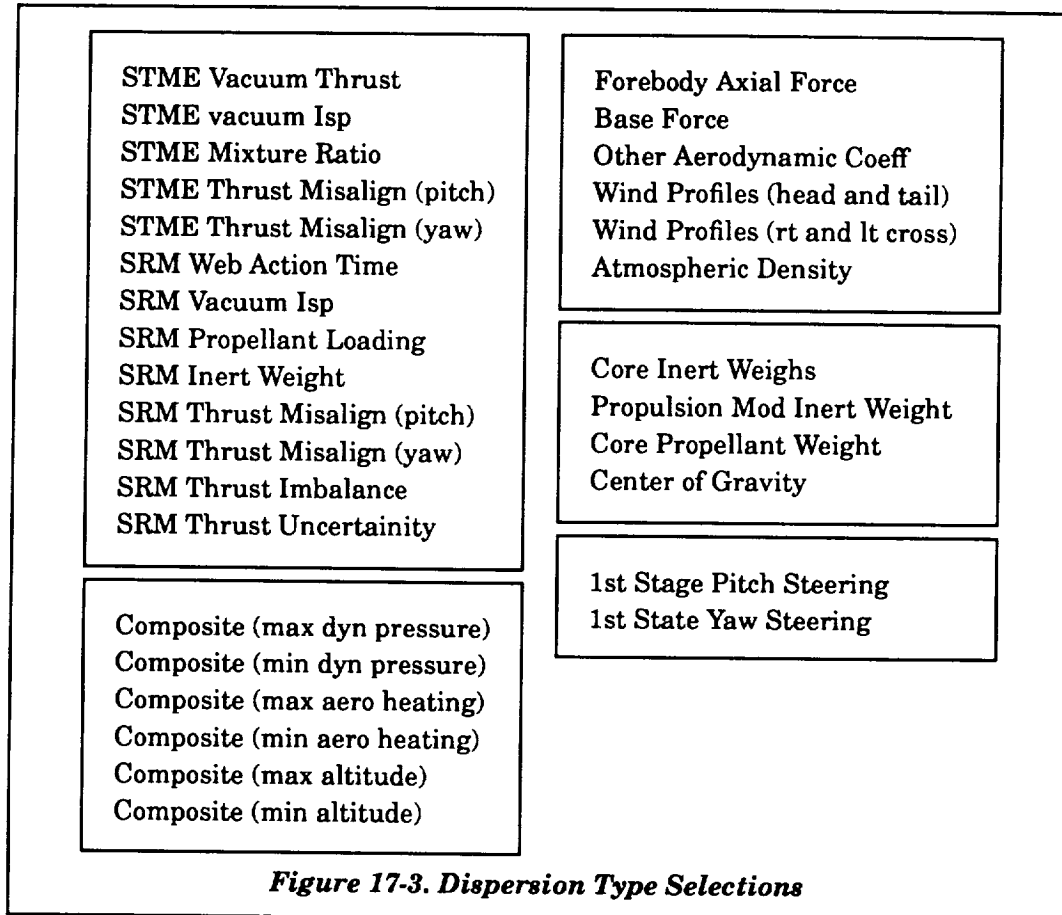
Table 17-1. Computer Requests to Build Command File

Enter title for this comfile [comfile]
Enter name of nonlinear aero data base [none]
Enter aero data Namelist file [*.anl]
Enter weight Namelist file [*.wnl]
Enter SRM data file [none]
Enter trajectory Namelist file [*.inl]
Enter alternate mass prop file [none]
Enter name of output plot file [none]
Enter name of dispersion data file [none]
Enter first-stage jump-start input file [none]
Enter first-stage jump-start output file [none]
Enter LOX table input file [none]
Enter LH2 table input file [none]
Printout menu [none]
Terminate [yes]

17.2 EDITING AN OLD COMMAND FILE

If the user wishes to review or edit an existing command file, the "Edit an old command file" item on the submenu is selected, which results in the display shown in **Figure 17-4**. This display also shows three windows: "Build," "Select," and "Edit Functions." After displaying these windows, the computer searches the user-defined directory for existing command files (i.e., those with a .COM extension) and lists the file names in the "Select" window. The user selects from this list by moving the cursor to the appropriate file name and pressing the Return Key. The command file is then displayed in the "Build" window, and the cursor is placed on the first record of the file. The up and down Arrow

Keys can then be used to move the cursor to the other records of the file. If the number of records of the file exceeds the size of the window, the user can scroll to the hidden records by moving the cursor to the top or bottom of the window and continue pressing the Arrow Key.

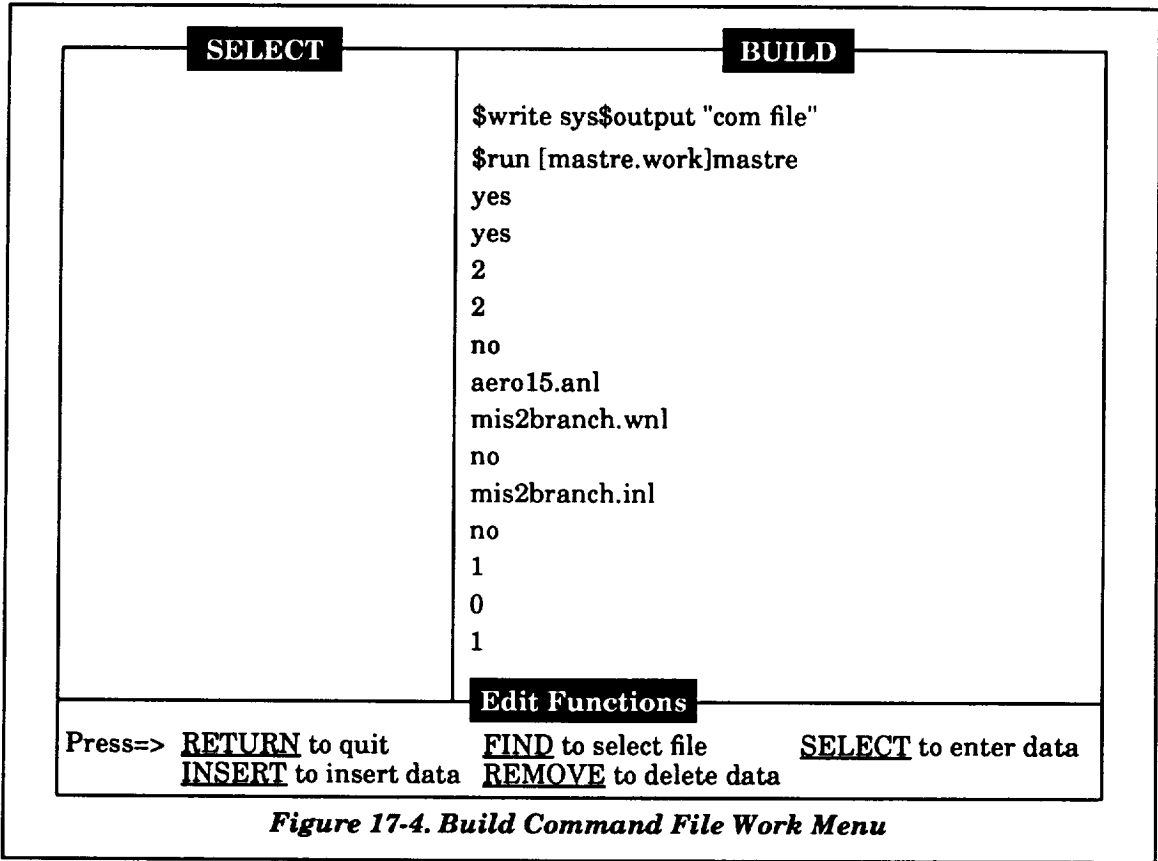


The function of the "Edit Functions" window is to provide editing information for the user. The user has a choice of four editing options. An entry can be changed by using the Select Key. This works in the same manner as changing data in many of the menus. A line of minus signs is displayed, which signifies that the user must type in the appropriate data and press the Return Key.

The second and third options allow the user to either delete or insert a record in the command file by using the Remove Key or Insert Here Key, respectively.

If the record is a file name, the fourth option allows the user to use the Find Key to find all file names in the current directory with the same extension. The list of file names is displayed in the "Select" window, and the user is required to select one of the file names. A file name is selected by moving the cursor to the desired file name and pressing the Return Key. The selected file name then

replaces the file name in the "Build" window. During the search, if no files are found, a message is displayed and no action is taken.



To terminate editing, the user presses the Return Key. The user will then be asked to provide a name for the edited command file. If the user does not want to save the edited command file, the Return Key must be immediately hit.

18. PLOT OUTPUT

If the user requests the MASTRE Program, via the command file, to generate a plot file (using a .PLT extension), the "Plot Output" item of the main menu can be selected after the MASTRE Program has been executed. The plot option allows the user to generate XY plots of user-selected parameters. The first screen, as shown in **Figure 18-1**, displays the four types of plotting devices that can be utilized. However, the user is currently restricted to the Terminal option. After selecting this option, the main plot menu shown in **Figure 18-2** is displayed. This menu provides seven options to the user. The "File" option allows the user to select the directory/subdirectory and the file name of the trajectory file to be printed. After selection of the file name, the menus shown in **Figure 18-3** are used to define the X and Y variables to be plotted. These variables replicate the variables in the trajectory block printout shown in Section 19. The user can use the up, down, left, and right Cursor Arrow Keys to high-light the variable name and press the Return Key. The definitions of the variable mnemonics used in this menu are also defined in Section 19. After pressing the Return Key, the variable name is displayed above the selection chart as shown in **Figure 18-3**. After selecting both the X and Y variables, the user is asked to verify his selection. If the selection is correct, the program reads the trajectory files, writes a plot file, and displays the number of points and the minimum and maximum of both X and Y variables (see **Figure 18-4**).

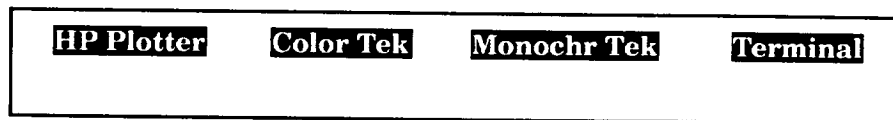


Figure 18-1. Plotting Devices

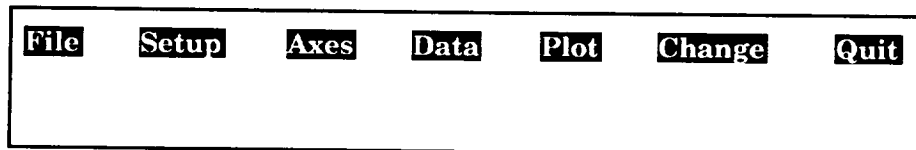


Figure 18-2. Plotting Main Menu

The "File" option is to be used only when the user wishes to define and initially read the trajectory file. Otherwise, the "Data" option can be selected. The "Data" option performs the same functions as the "File" option except that it does not allow the user to define the trajectory file.

The "Setup" option allows the user to choose between automatic and manual scaling (see **Figure 18-5**). If automatic scaling is selected, the user is returned to the main plot menu. If manual scaling is selected, a series of menus, as shown in **Figure 18-6**, are displayed to scale the X and Y

variables based on the user-specified chart size, the maximum and minimum data displayed, and tick mark spacing. The user is also asked for requirements for log scale and grid lines.

x-axis is TIME

Select X Variable

TIME	VSUBE	GAME	AZE	THRST	XMLB	R	VSUBI	GAMI	AZI
GCLAT	LONG	ALT	VSUBR	GAMR	AZR	GDLAT	NODE	Z8-X	X8-Y
Y8-Z	ZD8-W	XD8-U	YD8-V	CHIP	CHYI	CHIR	TIMP	LTIMP	LNGMP
THER	PSIR	PHIR	INCL	RANGE	RNGAN	THMPS	THSRM	THLBM	THOMS
...									

x-axis is TIME y-axis is ALT
 Is this correct ? (y,n)

Select Y Variable

TIME	VSUBE	GAME	AZE	THRST	XMLB	R	VSUBI	GAMI	AZI
GCLAT	LONG	ALT	VSUBR	GAMR	AZR	GDLAT	NODE	Z8-X	X8-Y
Y8-Z	ZD8-W	XD8-U	YD8-V	CHIP	CHYI	CHIR	TIMP	LTIMP	LNGMP
THER	PSIR	PHIR	INCL	RANGE	RNGAN	THMPS	THSRM	THLBM	THOMS
...									

Please wait - Reading the file

Figure 18-3. Variable Selection Menu

File Info

242 Points came across from file BRANCH_PLOT.PLT:!

X-values ranged from 0.00 to 486.81

Y-values ranged from -23.75 to 502506.00

Figure 18-4. Data Summary

chart format	
Automatic Scaling	Manual Scaling

Figure 18-5. Scaling Menu

Chart size horizontal (in.)								
9.	8.	7.	6.	5.	4.	3.	2.	1.

Chart size vertical (in.)					
6.	5.	4.	3.	2.	1.

is this a log scale (x-axis)	
no	yes

is this a log scale (y-axis)	
no	yes

x-grid lines on this plot	
no	yes

y-grid lines on this plot	
no	yes

Figure 18-6. Scaling Menus

specify origin of x-axis

x-axis origin ==>

specify origin of y-axis

y-axis origin ==>

specify axes extent . . .

max x =

min x =

max y =

min y =

Tic Locations

x spacing =

y spacing =

**** Labels ****

x-axis default TIME y-axis default ALT

Type new labels or return for defaults

Enter x-axis label =>

Enter y-axis label =>

Figure 18-6. Scaling Menus (Concluded)

The "Axes" option is currently not available under the terminal option. The "Change" option allows the user to change plotting devices. However, since the terminal option is the only one available, the "Change" option is not applicable.

The "Plot" option plots the variables to the terminal screen. The user can clear the screen and return to the main plot menu by pressing the Return Key.

The plot output is terminated by selecting the "Quit" option.

19. MASTRE PROGRAM OUTPUT DESCRIPTION

The output for the MASTRE Program is described in this section. The output is divided into the following groups: initial output, trajectory block output, iteration output, and post processor output. The initial output, trajectory block output, and the iteration output are contained in the FOR031.DAT output file. Portions of the post processor output are contained in the FOR031.DAT, FOR021.DAT, and FOR007.DAT output files. The following subsections present examples of these output printouts, describe the variables defined within, and define which output medium is used for output.

19.1 INITIAL OUTPUT

Initial output is printed on the FOR031.DAT file and is used to output the input variables from the general and aerodynamic Namelist files (\$INPUT and \$AEROIN, respectively). This output describes the current status of these variables in memory. The first output is a function of whether nonlinear aerodynamics are being simulated. If nonlinear aerodynamics are being simulated, multiple aerodynamic tabular data consisting of the axial, normal, and yaw force coefficients and the pitching, yawing, and rolling moment coefficients are output; otherwise, these tables are omitted. A tabular listing of the linear aerodynamic coefficients versus Mach number follows the nonlinear data or is the first output if nonlinear aerodynamics are not simulated. This output is followed by tabular data of base force data versus altitude, which is followed by tabular data of wind speed and direction versus altitude.

The aerodynamic Namelist data, under the name \$AEROIN, are the next data to printed. The variable names associated with the inputs are equated with the input data. The general trajectory Namelist data, under the name \$INPUT, are printed next. In a multiple run job, one consisting of more than one trajectory simulation, the aerodynamic Namelist will only appear on the first trajectory simulation (the assumption is that the aerodynamic data will not change when in a multiple-run mode).

19.2 TRAJECTORY BLOCK OUTPUT

Parameters associated with the equations of motion, as well as other pertinent data, are printed in the trajectory block output. Printing of the block output occurs whenever the user requests that the trajectory be printed. The usual mode is for the trajectory printout to occur on the first (or nominal) and converged trajectories. The printing of the block output occurs when describing discrete events (i.e., staging, thrust event initiation, maximum dynamic pressure) or when the print interval requires a printout. A page of output, as shown in *Figure 19-1*, consists of two blocks of print. The

MASTRE CASE- 1.0000 1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY PAGE 1 (AERO-2/83 REV IVBC-3)
(ATMOS - pra63.)
LIFT-OFF stage - 1

TIME 1.00000000E+00 VSURE 2.33117695E-14 GAME 0.00000000E+00 AZE 9.00000001E+01 THRST 3.30708991E+06 XMLB 2.03082145E+06
R 2.09097164E+07 VSUBI 1.34066442E+03 GAMI 3.19624126E-25 AZI 9.00000001E+01 GCLAT 2.84465160E+01 LONG-8.06040000E+01
ALT 1.03173394E+03 VSUBR 1.15059924E+00 GAMR 3.28568981E-19 AZR 7.82976073E+01 GDLAT 2.86080001E+01 NODE 9.00000001E+01
Z8-X 1.05777619E-04 X8-Y 2.09096333E+07 Y8-Z 5.89324298E+04 ZD8-W 1.34066442E+03 XD8-U 0.00000000E+00 YD8-V 2.40635404E-06
CHIP-7.40530595E-25 CHIY 2.65835173E-33 CHIR 1.80000000E+02 TIMP 0.00000000E+00 LTIMP 2.84465160E+01 LNCMP-8.06040000E+01
THERI 9.00000000E+01 PSIRI 9.00000000E+01 PHIRI 1.80000000E+02 INCL 2.84465161E+01 RANGE 0.00000000E+00 TH 0.00000000E+00
THEPS 3.30708991E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00 THOMS 0.00000000E+00 TFRCS 0.00000000E+00 TVAC 0.00000000E+00
TVNPS 3.90000000E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00 TVNPS 3.90000000E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00
ISPMF 4.28500000E+02 ISPSR 0.00000000E+00 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00 WDOT 0.00000000E+00
WDNPS 9.10151693E+03 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00 WDOT 0.00000000E+00 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00
MPS F 1.78104500E+06 SRM F 0.00000000E+00 SRM D 0.00000000E+00 RCS F 0.00000000E+00 RCS D 0.00000000E+00
MPS D 2.91038305E-11 SRM D 0.00000000E+00 SRM F 0.00000000E+00 RCS F 0.00000000E+00 RCS D 0.00000000E+00
DPNPS 0.00000000E+00 DYSRM 0.00000000E+00 DYLEM 0.00000000E+00 DPCMS 0.00000000E+00 DPCMS D 0.00000000E+00
DYNPS 0.00000000E+00 DYRING 0.00000000E+00 DYRNG 0.00000000E+00 DYRCS 0.00000000E+00 DYRCS D 0.00000000E+00
TAU 1.00000000E+00 GV L 0.00000000E+00 GV R 0.00000000E+00 SRMET 0.00000000E+00 SRMET 0.00000000E+00
TN L 0.00000000E+00 ALPHA 0.00000000E+00 BETA 1.50015571E-01 FAA 1.50015571E-01 FAS 0.00000000E+00 FAN 0.00000000E+00
MACH 1.01180844E-03 Q 1.51252476E-03 QALPH 0.00000000E+00 QETA 0.00000000E+00 QVIND 3.50702649E-01 AZM 7.82976073E+01 HEAT 0.00000000E+00
DRAG 1.50015571E-01 LIFT 0.00000000E+00 WIND 3.50702649E-01 AZM 7.82976073E+01 HEAT 0.00000000E+00
PRESS 2.11046905E+03 REO 1.17763549E+00 TEMP 2.98947833E+02 REYNO 7.40296538E+05 DELPC 0.00000000E+00 DELYC 0.00000000E+00
EMACH 2.04997921E-17 INED 0.00000000E+00 OUTED 0.00000000E+00 OPEN 0.00000000E+00 OPEN 0.00000000E+00
XCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00
AMX 0.00000000E+00 AMY 0.00000000E+00 AMZ 0.00000000E+00 AMZ 0.00000000E+00 AMZ 0.00000000E+00
olow 0.00000000E+00 wint 2.03082145E+06 thias 0.00000000E+00 z acc 2.56370565E-11 y acc 6.15135702E+00 z acc-1.42833053E-02
BEGIN TILT

TIME 1.00000000E+01 VSURE 2.15595285E+02 GAME 8.98286700E+01 AZE-1.39742873E+01 THRST 3.32859262E+06 XMLB 1.93980628E+06
R 2.09107719E+07 VSUBI 1.35780195E+03 GAMI 8.98286700E+01 AZI 8.99732618E+01 GCLAT 2.84465242E+01 LONG-8.06040015E+01
ALT 1.03173394E+03 VSUBR 2.15618868E+02 GAMR 8.91354337E+01 AZR 1.41410520E+02 GDLAT 2.86080083E+01 NODE 9.00979122E+01
Z8-X 1.34068257E+04 X8-Y 2.09106845E+07 Y8-Z 5.89300655E+04 ZD8-W 1.34071396E+03 XD8-U 2.14736997E+02 YD8-V 4.86076388E-01
CHIP 3.6679907E-02 CHIY-6.40360426E-06 CHIR 1.80000000E+02 TIMP 6.71528932E+00 LTIMP 2.84465323E+01 LNCMP-8.06040061E+01
THERI 9.00000000E+01 PSIRI 8.99999936E+01 PHIRI 1.80000000E+02 INCL 2.84465359E+01 RANGE 0.00000000E+00 TH 0.00000000E+00
THEPS 3.32859262E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00 THOMS 0.00000000E+00 TFRCS 0.00000000E+00 TVAC 0.00000000E+00
TVNPS 3.90000000E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00 TVNPS 3.90000000E+06 TVSRM 0.00000000E+00 TVLBM 0.00000000E+00
ISPMF 4.28500000E+02 ISPSR 0.00000000E+00 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00 WDOT 0.00000000E+00
WDNPS 9.10151693E+03 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00 WDOT 0.00000000E+00 WDSRM 0.00000000E+00 WDRCS 0.00000000E+00
MPS F 1.69002983E+06 SRM F 0.00000000E+00 SRM D 0.00000000E+00 RCS F 0.00000000E+00 RCS D 0.00000000E+00
MPS D 9.10151693E+04 SRM D 0.00000000E+00 SRM F 0.00000000E+00 RCS F 0.00000000E+00 RCS D 0.00000000E+00
DPNPS 0.00000000E+00 DYSRM 0.00000000E+00 DYLEM 0.00000000E+00 DPCMS 0.00000000E+00 DPCMS D 0.00000000E+00
DYNPS 0.00000000E+00 DYRING 0.00000000E+00 DYRNG 0.00000000E+00 DYRCS 0.00000000E+00 DYRCS D 0.00000000E+00
TAU 1.00000000E+00 GV L 0.00000000E+00 GV R 0.00000000E+00 SRMET 0.00000000E+00 SRMET 0.00000000E+00
TN L 0.00000000E+00 ALPHA-5.39597260E-01 BETA-8.37045616E-01 FAA 7.25984736E+03 FAS 6.78236732E+02 FAN-3.58857708E+02
MACH 1.90362350E-01 Q 5.15963497E+01 QALPH-2.78412489E+01 QETA-4.31884984E+01 AZM 4.69092723E+03 FNB 0.00000000E+00
DRAG 7.26280499E+03 REO 1.14393675E+00 TEMP 2.96589143E+02 REYNO 1.45411085E+02 HEAT 2.19530732E-03 HEATE 9.23742387E-04
PRESS 2.03392653E+03 RHO 1.14393675E+00 INED 0.00000000E+00 OUTED 0.00000000E+00 OPEN 0.00000000E+00 OPEN 0.00000000E+00
EMACH 1.90341529E-01 INED 0.00000000E+00 OUTED 0.00000000E+00 OPEN 0.00000000E+00 OPEN 0.00000000E+00
XCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00 ZCG 0.00000000E+00
AMX 4.68290897E+05 AMY 0.00000000E+00 AMZ-2.67406356E+05 AMZ 0.00000000E+00 THY 0.00000000E+00 THY 0.00000000E+00
olow 0.00000000E+00 wint 2.03082145E+06 thias 0.00000000E+00 z acc 2.64548406E-03 y acc 6.97364915E+00 z acc-1.77113955E-02

Figure 19-1. Trajectory Block Printout

caption at the upper left hand corner of the block identifies the significance of the particular printout (the caption "LIFT OFF" in the example printout). If a caption is not shown, either a print interval has been completed or a thrust event has been terminated. Discrete events are described by the captions shown in **Table 19-1**.

Table 19-1. Discrete Event Descriptions

Captions	Description
IGNITION	Initiation of the trajectory from the launch site or jump-start conditions
LIFT-OFF	Initial movement of the vehicle from the launch site when total acceleration, less gravity, is equal to one
THRUST EVENT	Beginning of a thrust event
BEGIN COAST	Beginning of a coast thrust event
END COAST	Coast thrust event termination
BEGIN TILT	Beginning of tilt-over maneuver
END TILT	Tilt-over maneuver termination
SRB SEPARATION	Separation of the SRBs
BEGIN MIN-H	Min-H attitude control has been initiated
LBM IGNITION	Begin simulation of LBM engines
LBM SEPARATION	Separation of the LBM
MAX DYN PRESS	Maximum dynamic pressure
BEGIN ROLL	Begin initial roll maneuver to place the vehicle pitch plane in the flight plane
END ROLL	End roll maneuver
BEGIN CHIFRZ	Begin pitch attitude freeze
CORE SEPARATION	Core stage separation
SEPARATION	Stage separation
INTERMEDIATE	Intermediate constraint
SHROUD JETTISON	Jettison of the shroud
G-LIMIT	Begin throttle to either maintain or reduce acceleration after hitting the limit
MPS THROTTLE	Discrete changes in the main propulsion system throttle history
WEIGHT DROP	Weight drop event
INJECTION	Trajectory termination

The block printout, as shown in **Figure 19-1**, consists of 24 lines of output. The variables are defined in **Table 19-2**.

Table 19-2. Block Output Variable Descriptions

Print Variable	Description	Units
Line 1		
TIME	Time from lift-off	s
VSUBE	Earth-fixed velocity	ft/s
GAME	Earth-fixed flight path angle	deg
AZE	Earth-fixed azimuth angle	deg
THRST	Total vehicle thrust	lbf
XMLB	Total weight	lbm
Line 2		
R	Radius from Earth's center	ft
VSUBI	Inertial velocity	ft/s
GAMI	Inertial flight path angle	deg
AZI	Inertial azimuth	deg
GCLAT	Geocentric latitude	deg
LONG	Longitude (positive east of Greenwich)	deg
Line 3		
ALT	Altitude above ellipsoid	ft
VSUBR	Relative velocity	ft/s
GAMR	Relative flight path angle	deg
AZR	Relative azimuth	deg
GDLAT	Geodetic latitude	deg
NODE	Inertial descending node	deg
Line 4		
Z8-X	Shuttle 8 Z position coordinate, MASTRE X coordinate	ft
X8-Y	Shuttle 8 X position coordinate, MASTRE Y coordinate	ft
Y8-Z	Shuttle 8 Y position coordinate, MASTRE Z coordinate	ft
ZD8-W	Shuttle 8 Z velocity coordinate, MASTRE W coordinate	ft/s
XD8-U	Shuttle 8 X velocity coordinate, MASTRE U coordinate	ft/s
YD8-V	Shuttle 8 Y velocity coordinate, MASTRE V coordinate	ft/s

Table 19-2. Block Output Variable Descriptions (Continued)

Print Variable	Description	Units
Line 5		
CHIP	Pitch attitude angle	deg
CHIY	Yaw attitude angle	deg
CHIR	Roll attitude angle	deg
TIMP	Time to predicted impact point (if terminated)	s
LTIMP	Geocentric latitude of instantaneous (vacuum) impact point	deg
LNGMP	Longitude of instantaneous (vacuum) impact point	deg
Line 6		
THERI	Pitch attitude angle in Boost Reference coordinate system	deg
PSIRI	Yaw attitude angle in Boost Reference coordinate system	deg
PHIRI	Roll attitude angle in Boost Reference coordinate system	deg
INCL	Inclination angle	deg
RANGE	Relative range from the launch site to the vehicle subpoint	nm
RNGAN	Inertial range angle between the launch site and the vehicle radius vector	deg
Lines 7 through 14 provide data for all the six propulsion systems; columns 1 through 6 represent the output of the MPS, SRM, LBM, OMS, RCS, and the fixed MPS, respectively.		
Line 7		
TH__	Total thrust of the propulsion system	lbf
Line 8		
TV__	Total vacuum thrust	lbf
Line 9		
ISP__	Vacuum specific impulse	s
Line 10		
WD__	Propellant flowrate	lbm/s
Line 11		
__ F	Propellant on board	lbm
Line 12		
__ D	Depleted propellant	lbm

Table 19-2. Block Output Variable Descriptions (Continued)

Print Variable	Description	Units
Line 13 DP__	Composite pitch gimbal angle	deg
Line 14 DY__	Composite yaw gimbal angle	deg
Line 15 TAU YRING PDOME SRMET ORBET CH VL	Throttle setting of MPS engines LOX bulkhead pressure indicator SRM-ET shear load indicator Orbiter-ET attach load indicator Characteristic velocity	--- psi lbf/m ² lbf lbf ft/s
Line 16 TN L GV L DR L BKP L GIM L ID VL	Turning losses Gravity losses Drag losses Back pressure losses Gimbal losses Ideal velocity	m/s m/s m/s m/s m/s m/s
Line 17 MACH ALPHA BETA FAA FAS FAN	Mach number AOA Sideslip angle Aerodynamic axial force Aerodynamic side force Aerodynamic normal force	--- deg deg lbf lbf lbf
Line 18 Q QALPH QBETA FAB FMB FNB	Dynamic pressure Product of Q and AOA Product of Q and sideslip angle Axial component of base force Base moment Normal component of base force	lbf/ft ² lbf-deg/ft ² lbf-deg/ft ² lbf lbf-m lbf

Table 19-2. Block Output Variable Descriptions (Continued)

Print Variable	Description	Units
Line 19		
DRAG	Aerodynamic drag force	lbf
LIFT	Aerodynamic lift force	lbf
VWIND	Wind speed	ft/s
AZW	Wind direction	deg
HEAT	Stagnation heating indicator	BTU
HRATE	Stagnation heating rate	BTU/s
Line 20		
PRESS	Atmospheric pressure	lb/ft ²
RHO	Atmospheric density	slugs/ft ³
TEMP	Atmospheric temperature	K
REYNO	Reynolds number	---
DELPC	Pitch misalignment of total thrust vector due to control	deg
DELYC	Yaw misalignment of total thrust vector due to control	deg
Line 21		
EMACH	Mach number based on Earth-fixed velocity	---
INBD	In-board elevon setting	deg
OUTBD	Out-board elevon setting	deg
AXACC	Total axial acceleration (less gravity)	g's
NRACC	Total normal acceleration (less gravity)	g's
LTACC	Total lateral acceleration (less gravity)	g's
Line 22		
XCG	Longitudinal component of CG	in.
ZCG	Normal component of CG	in.
QPEN	Dynamic pressure penalty function	lbf/ft ²
HAERO	Reference altitude for aerodynamics	ft
HATMOS	Reference altitude for atmosphere	ft
FOM	Total acceleration	g's

Table 19-2. Block Output Variable Descriptions (Concluded)

Print Variable	Description	Units
Line 23		
AMX	Body X component of aerodynamic moment	nt-m
AMY	Body Y component of aerodynamic moment	nt-m
AMZ	Body Z component of aerodynamic moment	nt-m
TMX	Body X component of thrust moment	nt-m
TMY	Body Y component of thrust moment	nt-m
TMZ	Body Z component of thrust moment	nt-m
Line 24		
LOW	Orbiter (or second stage) lift-off weight	lbm
WINT	Initial weight of current stage	lbm
TBIAS	Time between current time and internal time (used for branch trajectory)	s
X ACC	Plumbline X coordinate acceleration component	m/s ²
Y ACC	Plumbline Y coordinate acceleration component	m/s ²
Z ACC	Plumbline Z coordinate acceleration component	m/s ²

19.3 ITERATION OUTPUT

The iteration output follows the trajectory output after each forward and backward simulation of the trajectory. The iteration consists of single variables, vectors, matrices, and other pertinent data associated with the iteration and optimization process. The amount of printout obtained is a function of the printout option described in Subsection 13.3. **Table 19-3** lists the outputs obtained using the various printout options. As shown in **Table 19-3**, an index number has been used to specify the various formats used in the iteration output. Each of these formats are discussed in the following subsections.

19.3.1 Trajectory Summary Table (Format 1)

Directly after the simulation of the forward trajectory, a trajectory summary table is printed that displays the value of the payoff function and the errors in the terminal and intermediate equality constraints for both the present and previous trajectories. Also displayed are the amounts of change requested from the algorithm, the amounts of change obtained, and the percentages of predictability. A example of the trajectory summary table is shown in **Figure 19-2**.

MASTRE CASE- 1.0000 1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY

	Mass	Velocity I	Gamma Iner	Radius	Inclination	Altitude	Velocity I	Gamma Iner	Radius	Inclination
OLD	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
NEW	0.19815E+06	-0.19343E+03	0.43640E+00	0.20479E+05	-0.21091E-01	0.12855E+05	-0.19203E+03	0.18962E+00	0.29046E+05	-0.45407E-01
ASK	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
GOT	0.19815E+06	-0.19343E+03	0.43640E+00	0.20479E+05	-0.21091E-01	0.12855E+05	-0.19203E+03	0.18962E+00	0.29046E+05	-0.45407E-01
PCNT	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

	Altitude
OLD	0.00000E+00
NEW	0.13122E+05
ASK	0.00000E+00
GOT	0.13122E+05
PCNT	0.00000E+00

Figure 19-2. Trajectory Summary Table

Table 19-3. Printout Options

Output Group	Option 2	Option 1	Option 0
Trajectory Block Output	All trajectories are printed giving discrete point printouts on the nonconverged trajectories and full printout on the converged trajectory.	Only first and converged trajectories are printed, the first giving only discrete points and the converged giving the full printout.	Same as Option 1
Iteration Output	All formats are printed. Control variable printout consists of all points in control table.	Same as Option 2 except control variable printout is printed full on the first trajectory and first and last points thereafter.	Formats 1, 2, 3, 4, 10, 12 (treated the same as Option 1), and 13.

19.3.2 Polynomial Coefficients Output (Format 2)

The polynomial coefficients required to define the booster pitch and yaw attitude during the tilt-over maneuver are printed as shown in *Figure 19-3*.

```

POLYNOMIAL COEFFICIENTS
AP 0.64018660E-03 0.19540985E-01 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
AY-0.11176398E-06 0.74274085E-04 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00

```

Figure 19-3. Polynomial Coefficients Table

19.3.3 Calculus of Variations (COV) Lambdas Output (Format 3)

The initiation time of the min-H phase is printed along with the seven variable associated with the Euler-Lagrangian multipliers of the COVs. These variables, as shown in *Figure 19-4*, are determined, with the exception of time, after the second iteration and are zero prior to this.

19.3.4 Influence Coefficients Output (Format 4)

This matrix of output provides the user with the partial derivatives, or influence coefficients, of the payoff and the constraints with respect to the optimization parameters. The size of this output varies as a function of the number of equality constraints (left-to-right on the page) and the number of optimization parameters (top-to-bottom). An example of the influence coefficients printout is shown in *Figure 19-5*.

COV LAMBDA5
0.159596E+03 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00

Figure 19-4. COV Lambdas Output

INFLUENCE COEFFICIENTS
-0.5622235E+04 0.8733579E+02 0.6504703E-01 0.2091953E+04 -0.6651838E-03 0.1275405E+04 0.1253205E+03 0.3998221E+00
0.7965895E+04 -0.1794870E-02 0.1464733E+04
-0.6880631E+03 0.000000E+00 -0.8534839E-14 0.000000E+00 -0.8881784E-14 0.000000E+00 0.2916248E+02 0.2712635E-02
-0.1741420E+02 -0.5161201E-03 0.5179359E+03
-0.6880631E+03 0.000000E+00 -0.8534839E-14 0.000000E+00 -0.8881784E-14 0.000000E+00 0.2931840E+02 0.4745385E-02
0.2539690E+02 -0.5165997E-03 0.000000E+00
-0.9645038E+03 0.3884084E+02 -0.7778450E-01 0.1334544E+02 -0.4792581E-03 0.6589199E+03 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
-0.9645038E+03 0.3943451E+02 -0.7381601E-01 0.5788292E+02 -0.4820135E-03 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00
-0.3300446E+05 0.3479529E-02 -0.1301365E+05
0.8115171E+02 -0.5844934E+00 -0.2040333E+05 0.1619621E-02 -0.1200009E+05 0.8700179E+02 -0.4658651E+00

Figure 19-5. Influence Coefficients Table

19.3.5 I-PSI-PSI Output (Format 5)

This output matrix provides the printout of the optimization weighting matrix, W_a , presented in the Engineering Manual, which is based on integrated values of the impulse functions. The size of this matrix is dependent on the number of equality constraints. An example of this matrix is shown in *Figure 19-6*.

19.3.6 PSUBI and WIBT Outputs (Format 6)

The output vectors entitled PSUBI and WIBT provide the elements of the W_b weighting matrix described in the Engineering Manual. The PSUBI array is the calculated weighting on each of the optimization parameters, and WIBT is the weighting array that is updated by the program to speed convergence. The W_b weighting matrix is made up of the products of these two arrays. An example output is shown in *Figure 19-7*.

19.3.7 Total I-SY-SY Matrix Output (Format 7)

The total I-SY-SY matrix output, as shown in *Figure 19-8*, displays the matrix product of the influence coefficients and the weighting matrix before inversion of the matrix. The number of elements of this matrix is a function of the number of terminal and intermediate constraints.

19.3.8 WGNU Output (Format 8)

The WGNU output variable shown in *Figure 19-9* is an indicator, or measure, of the overall improvement of the payoff function on an iteration-by-iteration process, however, the constraints must be small.

19.3.9 XKAY and E1 Outputs (Format 9)

The XKAY and E1 output variables, as shown in *Figure 19-10*, are the current values of the restoration and optimization step control variables. XKAY, or k , is the restoration control step variable and E1, or E , is the optimization control step variable.

19.3.10 DRHO, WDS, and GNU Outputs (Format 10)

The DRHO, WDS, and GNU output, as shown in *Figure 19-11*, is a matrix of variables where the columns denote the DRHO, WDS, and GNU values and the rows are associated with each of the terminal and intermediate constraints. DRHO is defined as the equality constraint errors to be addressed by the restoration step, WDS is defined as the product of the inverse of the total ISYSY matrix and the DRHO vector, and GNU is defined as the partial derivatives of the payoff with respect to each constraint.

I PSI PSI
0.0000000E+00 0.22900097E+03-0.26183547E+01-0.71075627E+05 0.32856153E-01-0.19876580E+05 0.00000000E+00 0.00000000E+00
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.0000000E+00 0.26183547E+01 0.25565559E+00 0.24369599E+04 0.65624931E-05 0.35251607E+03 0.00000000E+00 0.00000000E+00
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.0000000E+00 0.71075627E+05 0.24369599E+04 0.33763807E+08 0.14070245E+00 0.70935571E+07 0.00000000E+00 0.00000000E+00
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.0000000E+00 0.32856153E-01 0.65624931E-05 0.14070245E+00 0.44948267E-02-0.22423736E-01 0.00000000E+00 0.00000000E+00
0.0000000E+00 0.0000000E+00 0.19876580E+05 0.35251607E+03 0.70935571E+07-0.22423736E-01 0.24130231E+07 0.00000000E+00
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
-0.24017060E+06 0.45563807E-01-0.17798701E+05 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.92632982E+01 0.22724934E+00
0.0000000E+00 0.83251805E-04 0.15800385E+03 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.36466001E+04 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00
0.97891854E+08 0.67239563E+00 0.74165171E+07 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.0000000E+04
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E-04
0.67239563E+00 0.99690237E-02-0.23533873E-02 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.45563807E-01 0.83251805E-04
0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+00 0.0000000E+03
0.74165171E+07-0.23533873E-02 0.15022820E+07 0.00000000E+00 0.0000000E+00 0.0000000E+00 0.17798701E+05 0.15800385E+03
0.74165171E+07-0.23533873E-02 0.15022820E+07

Figure 19-6. I-PSI-PSI Output Table

PSUBI
0.30022907E-01 0.69456493E+00 0.68719685E+00 0.15179585E+00 0.14725983E+00 0.14725983E+00 0.88706035E-02
WIBT
0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01

Figure 19-7. PSUBI and WIBT Output

TOTAL I SY SY MATRIX
0.18813805E+07
-0.26029508E+05 0.97442211E+03-0.37558193E+01-0.79863192E+05 0.26653141E-01-0.21285906E+05 0.39122934E+03 0.71300346E+00
-0.28715783E+04-0.22014947E-02-0.55274279E+04 0.25460460E+04 0.77643512E-05 0.40944493E+03-0.20634916E+00 0.31962354E-02
0.10892864E+02-0.37558193E+01 0.26054392E+00 0.25460460E+04 0.77643512E-05 0.40944493E+03-0.20634916E+00 0.31962354E-02
0.18667843E+03-0.21545906E-04 0.70333787E+02 0.37588512E+08-0.19929005E+00 0.93468920E+07-0.78754968E+04 0.10942832E+03
-0.36328820E+06-0.79863192E+05 0.25460460E+04 0.37588512E+08-0.19929005E+00 0.93468920E+07-0.78754968E+04 0.10942832E+03
0.64737844E+07-0.74248926E+00 0.24473339E+07 0.26653141E-01 0.77643512E-05-0.19929005E+00 0.44949323E-02-0.26823624E+00-0.12527890E-02-0.14677843E-04
0.25090901E+00 0.26653141E-01 0.77643512E-05-0.19929005E+00 0.44949323E-02-0.26823624E+00 0.38051540E+07-0.44624809E+04 0.64900206E+02
-0.53326080E+00 0.85835403E-07-0.21621924E+00 0.93468920E+07-0.26823624E+00 0.38051540E+07-0.44624809E+04 0.64900206E+02
-0.31115407E+06-0.21285906E+05 0.40944493E+03 0.93468920E+07-0.26823624E+00 0.38051540E+07-0.44624809E+04 0.64900206E+02
-0.38182881E+07-0.43911744E+00 0.14413652E+07 0.78754968E+04-0.12527890E-02-0.44624809E+04 0.23107405E+04-0.79679553E+01
-0.48953234E+05 0.39122934E+03-0.20634916E+00 0.78754968E+04-0.12527890E-02-0.44624809E+04 0.23107405E+04-0.79679553E+01
-0.23551154E+06 0.20633646E-01-0.11840139E+05 0.10942832E+03-0.14677843E-04 0.64900206E+02-0.79679553E+01 0.23399451E+00
-0.71028478E+02 0.71300346E+00 0.31962354E-02 0.10942832E+03-0.14677843E-04 0.64900206E+02-0.79679553E+01 0.23399451E+00
0.38786624E+04 0.44670257E-04 0.23034107E+03 0.64737844E+07-0.63326080E+00 0.38182881E+07-0.23551154E+06 0.38786624E+04
-0.13482963E+07-0.28715783E+04 0.18667843E+03 0.78754968E+04-0.21545906E-04-0.74248926E+00 0.11570559E+08
0.10946033E+09-0.7783820E+00 0.11570559E+08 0.97891854E+08-0.22014947E-02-0.21545906E-04-0.74248926E+00 0.11570559E+08
0.7938927E+00-0.22014947E-02-0.21545906E-04-0.74248926E+00 0.85835403E-07-0.43911744E+00 0.20633646E-01 0.44670257E-04
-0.7783820E+00 0.99695963E-02-0.66862619E+00 0.99695963E-02-0.66862619E+00 0.24473339E+07-0.21621924E+00 0.14413652E+07-0.11840139E+05 0.23034107E+03
-0.49476483E+06-0.55274279E+04 0.70333787E+02 0.24473339E+07-0.21621924E+00 0.14413652E+07-0.11840139E+05 0.23034107E+03
0.11570558E+08-0.66862619E+00 0.32552989E+07

Figure 19-8. Total I-SY-SY Matrix Output Table

WGNU 0.18806423E+07

Figure 19-9. WGNU Output Variables

XKAY 0.25000000E+00 E1 0.00000000E+00

Figure 19-10. XKAY and E1 Outputs

```
DRHO,WDS,GNU
0.48356354E+02 0.37783469E-01 0.23100025E+02
-0.10910029E+00-0.15890812E+01-0.71956037E+03
-0.51197328E+04 0.36864487E-03 0.98991634E-01
0.52728039E-02 0.87507703E+00-0.17135260E+03
-0.32136723E+04-0.10638470E-02 0.11568424E-01
0.48006333E+02 0.18686029E-01 0.23396755E+02
-0.47404493E-01-0.53390378E+00 0.91365492E+02
-0.72614819E+04 0.12208996E-03 0.53241282E-01
0.11351752E-01 0.10274139E+01-0.11176623E+03
-0.32805886E+04-0.10433235E-02 0.16573155E-01
```

Figure 19-11. DRHO, WDS, andGNU Outputs

19.3.11 Parameter Update and Convergence Test Output (Format 11)

As shown in **Figure 19-12**, the variables defined in **Table 19-4** are printed or can be printed depending on the user's choice of optimization parameters.

```
DPAR      OLD PCON      NEW PCON      P SCALE
ANEWCH I BETCON      1 T
0.12552734E+00 0.00000000E+00-0.22078328E-02 0.56222356E+04
ANEWCH I BETCON      2 T
0.31370607E-03 0.00000000E+00 0.32069708E-02 0.68806311E+03
ANEWCH I BETCON      3 T
0.37650207E+00 0.00000000E+00-0.38377839E-03 0.68806311E+03
ANEWCH I BETCON      4 T
0.13580540E+00 0.00000000E+00-0.23667236E-02 0.96450383E+03
ANEWCH I BETCON      5 T

ANEWCH I BETCON      6 T
0.18332926E+00 0.00000000E+00 0.76257576E-01 0.20464266E+04
TAUT( 2)= 0.11872153E+03
TAUT( 4)= 0.85000314E+02
TAUT( 5)= 0.23917150E+03
TAUT( 6)= 0.75135805E+02
GOING FALSE ON TAUT DBETA      96.03176681249458      0.2397668124945776
TAUT( 7)= 0.96031767E+02
AFTER 143 BETCON F
CPTBL F
CPTBL( 2)= 0.22612329E+02
```

Figure 19-12. Parameter Update and Convergence Test Output

19.3.12 Control Variable Update Output (Format 12)

The previous and updated values of the control variables (i.e., the pitch and yaw attitude angles) and the increments determined by the min-H algorithm are printed in this output, as shown in **Figure 19-13**. These angles and increments are printed in degrees and should be used for the next

guess values if the trajectory does not converge. If the output option has a value of either zero or one, the complete list of tables is printed after the first trajectory iteration, and a compact list showing only the first and last value of each attitude control phase is printed thereafter. If the output option is equal to two, the complete list is printed after each iteration.

Table 19-4. Parameter Update and Convergence Test Variables

Variable	Description
DPAR	Parameter update requirement (one per optimization parameter)
OLD PCON	Convergence factors from previous iteration (one per optimization parameter)
NEW PCON	Convergence factors for current iteration (one per optimization parameter)
P SCALE	Convergence parameter normalization factor (one per optimization parameter)
TAUT(I)	If the ith thrust event time is being optimized, the updated value is printed
W01	If lift-off weight is being optimized, the updated value is printed
AZ	If launch azimuth is being optimized, the updated value is printed
CPTBL(I)	If the ith value of the First stage pitch attitude table is being optimized, the updated value is printed
CYTBL(I)	If the ith value of the First stage yaw attitude table is being optimized, the updated value is printed
THROTTLE PAR (1)	If MPS throttle-down time is being optimized, the updated value is printed
THROTTLE PAR (2)	If time after max Q is being optimized, the updated value is printed
THROTTLE PAR (3)	If throttle level is being optimized, the updated value is printed
SIDESLIP PAR (I)	If sideslip angles are being optimized, the updated value is printed

19.3.13 Convergence Indicator Output (Format 13)

Directly after the control variable update printout is an output that displays the maximum increment (or decrement) required (in radians) when updating the pitch and yaw attitude angle tables. (An example output is shown in **Figure 19-14**.) When both of the maximum increment values are less than 0.005 and all the other convergence tests are met, the logical word BETCON is output as a T, or true, which indicates that convergence has occurred. If BETCON is F, or false, the iteration process continues. The fourth word on this line is the parameter KAT, which is used to indicate that an ill-conditioned matrix has been encountered during the determination of the W_a weighting matrix in the backward trajectory simulation. If KAT is equal to one, which indicates an ill-conditioned matrix, the user should terminate the current iterations. When KAT is equal to zero, no problems have been encountered.

TIME	NEW CP	OLD CP	NEW CY	OLD CY	DCP	DCY	
0.1595960E+03	0.6798768E+02	0.6458000E+02	0.1107944E+01	0.1099000E+01	0.3407682E+01	0.8943868E-02	1
0.1626317E+03	0.6815817E+02	0.6488109E+02	0.1106866E+01	0.1097927E+01	0.3277073E+01	0.8938889E-02	2
0.1656674E+03	0.6833460E+02	0.6519181E+02	0.1105768E+01	0.1096820E+01	0.3142793E+01	0.8948244E-02	3
0.1687031E+03	0.6850862E+02	0.6550252E+02	0.1104700E+01	0.1095713E+01	0.3006101E+01	0.8986717E-02	4
0.1717389E+03	0.6868057E+02	0.6581324E+02	0.1103662E+01	0.1094606E+01	0.2867329E+01	0.9056697E-02	5
0.1747746E+03	0.6885101E+02	0.6612395E+02	0.1102658E+01	0.1093499E+01	0.2727055E+01	0.9158995E-02	6
0.1778103E+03	0.6902019E+02	0.6643466E+02	0.1101686E+01	0.1092391E+01	0.2585523E+01	0.9294130E-02	7
0.1808460E+03	0.6918829E+02	0.6674538E+02	0.1100747E+01	0.1091284E+01	0.2442906E+01	0.9462355E-02	8
0.1838817E+03	0.6935540E+02	0.6705609E+02	0.1099841E+01	0.1090177E+01	0.2299309E+01	0.9663806E-02	9
0.1869174E+03	0.6952163E+02	0.6736681E+02	0.1098968E+01	0.1089070E+01	0.2154819E+01	0.9898497E-02	10
0.1899531E+03	0.6968701E+02	0.6767752E+02	0.1098129E+01	0.1087963E+01	0.2009487E+01	0.1016640E-01	11
0.1929889E+03	0.6985158E+02	0.6798824E+02	0.1097323E+01	0.1086856E+01	0.1863346E+01	0.1046747E-01	12
0.1960246E+03	0.7001536E+02	0.6829895E+02	0.1096550E+01	0.1085749E+01	0.1716412E+01	0.1080171E-01	13
0.1990603E+03	0.7017837E+02	0.6860966E+02	0.1095810E+01	0.1084641E+01	0.1568707E+01	0.1116907E-01	14
0.2020960E+03	0.7034062E+02	0.6892038E+02	0.1095104E+01	0.1083534E+01	0.1420245E+01	0.1156950E-01	15
0.2051317E+03	0.7050213E+02	0.6923109E+02	0.1094430E+01	0.1082427E+01	0.1271038E+01	0.1200298E-01	16
0.2081674E+03	0.7066290E+02	0.6954181E+02	0.1093789E+01	0.1081320E+01	0.1121095E+01	0.1246950E-01	17
0.2112031E+03	0.7082295E+02	0.6985252E+02	0.1093182E+01	0.1080213E+01	0.9704281E+00	0.1296900E-01	18
0.2142389E+03	0.7098228E+02	0.7016324E+02	0.1092607E+01	0.1079106E+01	0.8190473E+00	0.1350146E-01	19
0.2172746E+03	0.7114091E+02	0.7047395E+02	0.1092065E+01	0.1077999E+01	0.6669625E+00	0.1406686E-01	20
0.2203103E+03	0.7129885E+02	0.7078466E+02	0.1091557E+01	0.1076891E+01	0.5141836E+00	0.1466515E-01	21
0.2233460E+03	0.7145610E+02	0.7109538E+02	0.1091081E+01	0.1075784E+01	0.3607198E+00	0.1529632E-01	22
0.2263817E+03	0.7161267E+02	0.7140609E+02	0.1090637E+01	0.1074677E+01	0.2065808E+00	0.1596034E-01	23
0.2294174E+03	0.7176858E+02	0.7171681E+02	0.1090227E+01	0.1073570E+01	0.5177623E-01	0.1665718E-01	24
0.2324531E+03	0.7192384E+02	0.7202752E+02	0.1089850E+01	0.1072463E+01	0.1036845E+00	0.1738680E-01	25
0.2354889E+03	0.7207844E+02	0.7233824E+02	0.1089505E+01	0.1071356E+01	0.2597918E+00	0.1814918E-01	26
0.2385246E+03	0.7223241E+02	0.7264895E+02	0.1089193E+01	0.1070249E+01	0.4165363E+00	0.1894430E-01	27
0.2415603E+03	0.7238576E+02	0.7295966E+02	0.1088914E+01	0.1069141E+01	0.5739084E+00	0.1977212E-01	28
0.2445960E+03	0.7253848E+02	0.7327038E+02	0.1088667E+01	0.1068034E+01	0.7318985E+00	0.2063261E-01	29
0.2475960E+03	0.7264783E+02	0.7338000E+02	0.1088636E+01	0.1068000E+01	0.7321652E+00	0.2063585E-01	30
0.2506244E+03	0.7273275E+02	0.7343378E+02	0.1088593E+01	0.1060426E+01	0.7051349E+00	0.2550816E-01	31
0.2531244E+03	0.7283010E+02	0.7354075E+02	0.1088311E+01	0.1052768E+01	0.6774579E+00	0.3034233E-01	32
0.2561652E+03	0.7293010E+02	0.7364772E+02	0.1088024E+01	0.1045109E+01	0.6488427E+00	0.3513313E-01	33
0.2592096E+03	0.7292758E+02	0.7374690E+02	0.1087733E+01	0.1037451E+01	0.6193245E+00	0.3988050E-01	34
0.2622380E+03	0.7292763E+02	0.7386165E+02	0.1087437E+01	0.1029792E+01	0.5889388E+00	0.4458438E-01	35
0.2652764E+03	0.7292852E+02	0.7396862E+02	0.1087137E+01	0.1022134E+01	0.5577215E+00	0.4924473E-01	36
0.2683248E+03	0.7293021E+02	0.7407559E+02	0.1086833E+01	0.1014476E+01	0.5257086E+00	0.5386153E-01	37
0.2713732E+03	0.7293265E+02	0.7418255E+02	0.1086525E+01	0.1006817E+01	0.4929364E+00	0.5843476E-01	38
0.2744216E+03	0.7293582E+02	0.7428952E+02	0.1086213E+01	0.9991587E+00	0.4594415E+00	0.6296442E-01	39
0.2774700E+03	0.7293967E+02	0.7439649E+02	0.1085951E+01	0.9915003E+00	0.4252608E+00	0.6745051E-01	40
0.2805184E+03	0.7294299E+02	0.7450428E+02	0.1085735E+01	0.9838419E+00	0.3904313E+00	0.7189306E-01	41
0.2835668E+03	0.7294685E+02	0.7461104E+02	0.1085247E+01	0.9761835E+00	0.3549904E+00	0.7629209E-01	42
0.2866152E+03	0.7295070E+02	0.7471739E+02	0.1084917E+01	0.9685251E+00	0.3189755E+00	0.8064765E-01	43
0.2896636E+03	0.7295456E+02	0.7482363E+02	0.1084582E+01	0.9608666E+00	0.2824244E+00	0.8495979E-01	44
0.2927120E+03	0.7295841E+02	0.7493000E+02	0.1084243E+01	0.9532082E+00	0.2453753E+00	0.8922857E-01	45
0.2957604E+03	0.7296226E+02	0.7503624E+02	0.1083904E+01	0.9455498E+00	0.2078662E+00	0.9345408E-01	46
0.2988088E+03	0.7296611E+02	0.7514248E+02	0.1083555E+01	0.9378914E+00	0.1699356E+00	0.9763638E-01	47
0.3018572E+03	0.7296996E+02	0.7524872E+02	0.1083209E+01	0.9302330E+00	0.1316223E+00	0.1017756E+00	48
0.3049056E+03	0.7297381E+02	0.7535496E+02	0.1082864E+01	0.9225746E+00	0.9296488E-01	0.1058718E+00	49
0.3079540E+03	0.7297766E+02	0.7546120E+02	0.1082519E+01	0.9149162E+00	0.5400252E-01	0.1099251E+00	50
0.3110024E+03	0.7298151E+02	0.7556744E+02	0.1082174E+01	0.9072578E+00	0.1477440E-01	0.1139356E+00	51
0.3140508E+03	0.7298536E+02	0.7567368E+02	0.1081829E+01	0.8995994E+00	0.2468012E-01	0.1179036E+00	52
0.3170992E+03	0.7298921E+02	0.7577992E+02	0.1081484E+01				53

Figure 19-13. Control Variable Update Output

DEL CHIP MAX= 0.9480E+00 DEL CHY MAX= 0.1794E+00 BETCON= F KAT= 0
VERSION NUMBER 2.00

Figure 19-14. Convergence Indicator Output

19.3.14 Summary Tables (Format 14)

At the conclusion of the converged trajectory iteration, the following tables are provided: the parameter summary table (shown in **Figure 19-15**), the orbital element summary table (shown in **Figure 19-16**), the load indicator table (shown in **Figure 19-17**), and the weight summary table (shown in **Figure 19-18**). Two tables are printed for both the orbital element summary table and the load indicator table if the branch trajectory is being simulated. The weight summary table format is vehicle system dependent, therefore, the current version of MASTRE has three weight summary formats consistent with the three vehicles systems that can be simulated. Variables defined in the orbital element summary table (**Figure 19-16**) are defined in **Table 19-5**.

19.4 POST PROCESSOR OUTPUT

This subsection describes the output provided by the two optional post processor modules.

19.4.1 Parameter Summary Table Post Processor

As discussed in Subsection 15.3, an optional set of parameter summary tables can be output on the FOR021.DAT file at the termination of the converged trajectory. A separate Namelist array, "INPUT2", is used to activate the table output. This Namelist array is defined in a separate file under the file name "ELTTBL.NL" and is automatically placed in the run stream when the parameter summary tables are requested. The inputs variables for this Namelist array are defined in **Table 19-6**. When using the parameter summary table, the user should modify the SRID arrays to allow the names of the events to be consistent with the vehicle events being simulated.

Currently, 14 publishable tables are output. An example of the output produced by these tables is shown **Figure 19-19**. After printing these tables, a summary table is provided that defines the variable names, the table index, the units, and the definitions of the variables.

19.4.2 Propulsion Output Table

Figure 19-20 is an example printout of the propulsion output table. As discussed in Subsection 15.3, this is an optional table and, when activated, is output on the FOR007.DAT file. The definition of the variables used in this table are defined in **Table 19-7**.

```

PARAMETERS
TAUT      0.40000000E+02 0.11916187E+03 0.10000000E+01 0.84309002E+02 0.24064780E+03 0.73056135E+02 0.99045523E+02 0.00000000E+00
          0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
WO1       0.20308214E+07
AZ        0.90000000E+02
CPTBL     0.36679991E-01 0.23473025E+02 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
CYTBL     -0.64036043E-05 0.10000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
THROTTLE PARAMETERS
          0.00000000E+00 0.00000000E+00 0.10000000E+01
SIDESLIP CONTROL
MARGIN    0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
          0.00000000E+00 0.00000000E+00

```

Figure 19-15. Parameters Summary Table

1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY

case =NOM

TIME	332.263527 SEC	RANGE	493.41 NM	RANGE ANGLE	9.428548 DEG
INERTIAL VELOCITY	7853.5011 M/SEC	RADIUS	6526321.56 M	FLIGHT PATH ANGLE	-0.000271 DEG
INCL	28.465700 DEG	DES. NODE	86.822780 DEG	FLIGHT AZIMUTH	90.000000 DEG
GDLAT	27.922883 DEG	GCLAT	27.763942 DEG	LONG	-71.327779 DEG
INERTIAL AZIMUTH	96.547644 DEG	C1	0.51254474E+11 M**2/SEC		
WEIGHT	214024.77 LBS	C3	-0.60474393E+08 M**2/SEC**2		
KEPLERIAN ORBITAL PARAMETERS					
ECNTRICY	0.009849	APOGEE RADIUS	6656157.27 M	PERIGEE RADIUS	6526321.55 M
APOGEE HEIGHT	150.106515 NM	PERIGEE HEIGHT	80.000838 NM		

Figure 19-16. Orbital Element Summary Table

1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY

case - NOM

LOAD INDICATOR	FIRST STAGE			SECOND STAGE			UNITS
	MINIMUM TIME	MINIMUM VALUE	MAXIMUM TIME	MINIMUM TIME	MINIMUM VALUE	MAXIMUM TIME	
Q ALPHA	9.00	-28.10	30.00	160.16	-26.99	332.26	LB-DEG/FT**2
Q BETA	30.00	-163.65	2.00	160.16	-3.99	299.06	LB-DEG/FT**2
Q	0.00	0.00	47.70	305.06	0.00	160.16	LB/FT**2
LONG ACC	160.16	1.31	159.16	160.16	1.81	297.06	G'S
LAT ACC	3.00	0.00	30.00	286.22	0.00	160.16	G'S
NORM ACC	30.00	-0.05	10.00	332.26	0.00	160.16	G'S
TOTAL ACC	160.16	1.31	159.16	160.16	1.81	297.06	G'S
STAG HEAT	0.00	0.00	160.16	160.16	278.32	332.26	BTU/FT**2
HEAT RATE	0.00	0.00	145.00	253.22	0.22	160.16	BTU/FT**2/S
PDOME	160.16	30.33	20.00	332.26	24.73	160.16	PSI
YRING	160.16	24.39	20.00	332.26	5.44	160.16	PSI

STAGING CONDITIONS

Time	160.162 sec	Wgt-pre	795015.6 lbs	Wgt-post	716703.6 lbs
Altitude	239251.0 ft	Vel Iner	10156.20 fps	Gamma I	13.94197 deg
Dyn Pres	4.392 psf	Vel Rel	8847.44 fps	Gamma R	16.05619 deg
Ax Acc	1.310 gs	Mach No.	9.32		

Figure 19-17. Load Indicator Table

1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY

	NOMINAL	ENGINE OUT
PAYLOAD	62368.	62368.
UPPER STAGE - JETTISON WEIGHT	0.	0.
- INERT STRUCTURE	0.	0.
- FLIGHT PERFORMANCE RESERVE	0.	0.
- DELTA VELOCITY PROPELLANT	0. (0. F/S)	0. (0. F/S)
- EXCESS PROPELLANT (PROP LD)	0. (0.)	0.
- FUEL BIAS	0.	0.
- PROP RESIDUALS/UNUSABLE	0.	0.
WEIGHT AT ORBIT INSERTION	62368.	62368.
UPPER STAGE - PROPELLANT BURNED	0.	0.
WEIGHT AFTER 2ND STAGE SEPARATION	62368.	62368.
PERFORMANCE MARGIN - PAYLOAD	0.	0.
- OTHER	0.	0.
2ND STAGE - JETTISON WEIGHT	151656.	148902.
- STAGE INERT WEIGHT (LESS ENG)	109350.	109350.
- NONPROPULSIVE CONSUMABLES	0.	0.
- DRY WEIGHT OF ENGINE(S)	18200.	18200.
2ND STAGE - TOTAL WEIGHT AT 2ND STAGE SEP	214025.	211270.
- PROP RESIDUALS/UNUSABLES	12761.	12761.
- FLIGHT PERFORMANCE RESERVE	5571.	5571.
- FUEL BIAS	0.	0.
- MPS THRUST BUILDUP	0.	0.
- BOILOFF, OVERFILL, DRAINBACK	0.	0.
EXCESS MPS PROPELLANT (MPS PROP LOADED)	5774. (1781045.)	3020. (0.)
SEROUD WEIGHT SEPARATED AT MECO	0.	0.
INJECTED WEIGHT AT MECO	214025.	211270.
SEROUD JETTISON WEIGHT	12500.	12500.
PROPELLANT BURNED - SEPARATION TO MECO	490179.	492933.
WEIGHT AT SEPARATION	716704.	

Figure 19-18. Weight Summary Table

1.5 STAGE MISSION 2 - 6/2 BRANCH TRAJECTORY

	NOMINAL	ENGINE OUT
WEIGHT AT SEPARATION		716704.
1ST STAGE - JETTISON WEIGHT	65962.	
- STAGE INERT WEIGHT (LESS ENG)	65962.	
- DRY WEIGHT OF ENGINE(S)	0.	
- NONPROPULSIVE CONSUMABLES	0.	
- FUEL BIAS	0.	
- PROP RESIDUALS/UNUSABLES	0.	
PROPELLANT BURNED - LIFTOFF TO SEPARATION	1235806.	
LIFTOFF (T/W=1.0)		2030821.
MPS PROPELLANT	0.	
IGNITION COMMAND (T-0)		2030821.
1ST STAGE - MPS THRUST BUILDUP	30954.	
- BOILOFF, OVERFILL, DRAINBACK	0.	
PRELAUNCH WEIGHT (T-5 MIN)		2061775.

Figure 19-18. Weight Summary Table (Concluded)

Table 19-5. Orbital Element Summary Variables

Variable	Description	Units
TIME	Time from lift-off	s
RANGE	Relative range from launch point	nm
RANGE ANGLE	Relative range angle	deg
INERTIAL VELOCITY	Inertial velocity magnitude	m/s
RADIUS	Radius from Earth's center	m
FLIGHT PATH ANGLE	Inertial flight path angle	deg
INCL	Inclination angle	deg
DES. NODE	Descending node	deg
FLIGHT AZIMUTH	Launch azimuth angle	deg
GDLAT	Geodetic latitude angle	deg
GCLAT	Geocentric latitude angle	deg
LONG	Longitude angle	deg
INERTIAL AZIMUTH	Inertial azimuth angle	deg
C1	Angular momentum magnitude	m ² /s
WEIGHT	Mass at injection	lbm
C3	Vis viva interval (twice the energy)	m ² /s ²
ECNTRICY	Orbital eccentricity	---
APOGEE RADIUS	Radius at apogee	m
PERIGEE RADIUS	Radius at perigee	m
APOGEE HEIGHT	Apogee altitude above equatorial radius	nm
PERIGEE HEIGHT	Perigee altitude above equatorial radius	nm

Table 19-6. "INPUT2" Namelist Variables

Variable	Type	Description	Size
NCASE	Int	Case index number	1
OFFICE	Char	Office symbol	char*12
TITLE	Char	Title simulation	char*48
DATE	Char	Date of simulation	char*12
SRID(30)	Char	Optional titles, SRID(1-15) are substituted for "THRUST EVENT" events and SRID(15-30) substituted for the "WEIGHT DROP" events	char*12
NOTAB	Int	Number of table	1

CASE 1

TABLE NO. 1

TIME	R	ALT	VSUBI	GAMI	ASI	GCLAT	GOLAT	LONG	INCL
LIFT-OFF									
0.00	20909716.	-24.	1340.66	0.000	90.00	28.45	28.608	-80.604	28.447
1.00	20909727.	-18.	1340.82	0.971	90.00	28.45	28.608	-80.604	28.447
2.00	20909737.	17.	1341.29	1.752	90.00	28.45	28.608	-80.604	28.447
3.00	20909809.	69.	1342.09	2.643	89.99	28.45	28.608	-80.604	28.447
4.00	20909881.	141.	1343.22	3.344	89.99	28.45	28.608	-80.604	28.447
5.00	20909975.	235.	1344.71	4.454	89.99	28.45	28.608	-80.604	28.447

CASE 1

TABLE NO. 2

TIME	VSUBR	GAME	AZE	VSUBR	GAMR	AZR	VWIND	AZW	RANGE
LIFT-OFF									
0.00	0.00	0.000	90.00	1.15	0.000	78.30	0.35	78.30	0.000
1.00	20.39	89.838	-1.31	20.42	86.667	76.28	0.36	79.02	0.000
2.00	41.01	89.838	-2.63	41.03	88.226	75.98	0.38	81.18	0.000
3.00	61.89	89.838	-3.98	61.91	88.707	77.57	0.42	84.77	0.000
4.00	83.03	89.838	-5.35	83.04	88.923	81.13	0.48	89.77	0.000
5.00	104.42	89.837	-6.76	104.44	89.036	86.66	0.55	96.13	0.000

CASE 1

TABLE NO. 3

TIME	Y8-X	Y8-Y	Y8-Z	YD8-W	YD8-U	YD8-V	AYACC	NRACC	LYACC
LIFT-OFF									
0.00	0.	20909633.	58932.	1340.66	0.00	0.00	1.628	0.000	0.000
1.00	1341.	20909643.	58932.	1340.67	20.30	-0.05	1.636	0.000	0.000
2.00	2681.	20909674.	58932.	1340.67	40.84	-0.09	1.643	0.000	0.000
3.00	4022.	20909725.	58932.	1340.67	61.63	-0.14	1.651	0.000	0.000
4.00	5363.	20909797.	58932.	1340.67	82.68	-0.19	1.659	0.000	0.000
5.00	6703.	20909891.	58932.	1340.68	103.99	-0.23	1.668	0.000	0.000

CASE 1

TABLE NO. 4

TIME	CH1P	CH1Y	CH1R	TEERI	PSIRI	PHIRI	DELPC	DELYC
LIFT-OFF								
0.00	0.000	0.000	180.000	90.000	90.000	180.000	0.000	0.000
1.00	0.004	0.000	180.000	90.000	90.000	180.000	0.000	0.000
2.00	0.007	0.000	180.000	90.000	90.000	180.000	0.000	0.000
3.00	0.011	0.000	180.000	90.000	90.000	180.000	0.000	0.000
4.00	0.015	0.000	180.000	90.000	90.000	180.000	0.000	0.000
5.00	0.018	0.000	180.000	90.000	90.000	180.000	0.000	0.000

CASE 1

TABLE NO. 5

TIME	TEMP5	TAU	TEMPM	TELEM	TECHS	TEHST
LIFT-OFF						
0.00	3307089.	1.00	0.	0.	0.	3307089.
1.00	3307299.	1.00	0.	0.	0.	3307299.
2.00	3307933.	1.00	0.	0.	0.	3307933.
3.00	3308994.	1.00	0.	0.	0.	3308994.
4.00	3310486.	1.00	0.	0.	0.	3310486.
5.00	3312412.	1.00	0.	0.	0.	3312412.

CASE 1

TABLE NO. 6

Figure 19-19. Parameter Summary Table

TIME	TIME	TVMS	ISPM	MEMS	MPS F	MPS D	DPMS	DYMS	TAU
LIFT-OFF	0.00	3307089.	428.50	9101.52	1750091.	30954.	0.00	0.00	1.00
	1.00	3307299.	428.50	9101.52	1740989.	40056.	0.00	0.00	1.00
	2.00	3307933.	428.50	9101.52	1731888.	49157.	0.00	0.00	1.00
	3.00	3308394.	428.50	9101.52	1722786.	58259.	0.00	0.00	1.00
	4.00	3310486.	428.50	9101.52	1713685.	67360.	0.00	0.00	1.00
	5.00	3312412.	428.50	9101.52	1704583.	76462.	0.00	0.00	1.00

CASE 1

TABLE NO. 7

TIME	THSRM	TVSRM	ISPSR	WDSRM	SRM F	SRM D	DPSRM	DYSRM	YSRM
LIFT-OFF	0.00	0.	0.00	0.00	0.	0.	0.00	0.00	51.34
	1.00	0.	0.00	0.00	0.	0.	0.00	0.00	51.47
	2.00	0.	0.00	0.00	0.	0.	0.00	0.00	51.61
	3.00	0.	0.00	0.00	0.	0.	0.00	0.00	51.76
	4.00	0.	0.00	0.00	0.	0.	0.00	0.00	51.91
	5.00	0.	0.00	0.00	0.	0.	0.00	0.00	52.08

CASE 1

TABLE NO. 8

TIME	EXLS	XCG	ZCG	MODE	RNGAN	RHO	REYNO
LIFT-OFF	0.00	0.00	0.00	90.000	0.000	0.002	740297.
	1.00	0.00	0.00	90.009	0.004	0.002	13135739.
	2.00	0.00	0.00	90.019	0.007	0.002	26378207.
	3.00	0.00	0.00	90.028	0.011	0.002	39752916.
	4.00	0.00	0.00	90.038	0.015	0.002	52440482.
	5.00	0.00	0.00	90.047	0.018	0.002	66824756.

CASE 1

TABLE NO. 9

TIME	THOMS	TVOMS	ISPOH	WDOMS	OMS F	OMS D	DPOMS	DYOMS
LIFT-OFF	0.00	0.	0.00	0.00	0.	0.	0.00	0.00
	1.00	0.	0.00	0.00	0.	0.	0.00	0.00
	2.00	0.	0.00	0.00	0.	0.	0.00	0.00
	3.00	0.	0.00	0.00	0.	0.	0.00	0.00
	4.00	0.	0.00	0.00	0.	0.	0.00	0.00
	5.00	0.	0.00	0.00	0.	0.	0.00	0.00

CASE 1

TABLE NO. 10

TIME	TYRCS	TVRCS	ISPRC	WDRCS	RCS F	RCS D	DPRCS	DYRCS
LIFT-OFF	0.00	0.	0.00	0.00	0.	0.	0.00	0.00
	1.00	0.	0.00	0.00	0.	0.	0.00	0.00
	2.00	0.	0.00	0.00	0.	0.	0.00	0.00
	3.00	0.	0.00	0.00	0.	0.	0.00	0.00
	4.00	0.	0.00	0.00	0.	0.	0.00	0.00
	5.00	0.	0.00	0.00	0.	0.	0.00	0.00

Figure 19-19. Parameter Summary Table (Continued)

CASE 1

TABLE NO. 11

TIME	WACE	ALPHA	BETA	Q	QALPH	QBETA	EMACH	INRD	OUTRD
LIFT-OFF									
0.00	0.001	0.000	0.000	0.00	0.	0.	0.00	0.00	0.00
1.00	0.018	-3.237	0.629	0.48	-2.	0.	0.02	0.00	0.00
2.00	0.036	-1.721	0.269	1.92	-3.	1.	0.04	0.00	0.00
3.00	0.054	-1.262	0.117	4.37	-6.	1.	0.05	0.00	0.00
4.00	0.073	-1.064	0.005	7.84	-8.	0.	0.07	0.00	0.00
5.00	0.092	-0.963	-0.105	12.37	-12.	-1.	0.09	0.00	0.00

CASE 1

TABLE NO. 12

TIME	CH VL	ID VL	IN L	GV L	DR L	BRP L	GIM L
LIFT-OFF							
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	52.51	61.93	52.11	0.24	0.00	9.41	0.00
2.00	105.27	124.13	103.66	0.98	0.00	18.86	0.00
3.00	158.28	186.62	154.64	2.22	0.00	28.34	0.00
4.00	211.55	249.39	205.04	3.95	0.00	37.84	0.00
5.00	265.09	312.45	254.85	6.20	0.00	47.36	0.00

CASE 1

TABLE NO. 13

TIME	FAA	FAB	DRAG	FAN	FNB	LIFT	FAS	FNB	PRESS
LIFT-OFF									
0.00	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	2110.5
1.00	49.4	47.1	49.5	-2.1	0.0	0.7	-0.5	0.0	2109.7
2.00	208.6	189.3	208.7	-8.8	0.0	-2.5	-1.7	0.0	2107.5
3.00	493.9	428.4	494.2	-21.9	0.0	-11.1	-2.5	0.0	2103.7
4.00	921.1	764.5	921.7	-44.1	0.0	-27.0	-0.2	0.0	2098.4
5.00	1505.2	1196.5	1506.3	-78.4	0.0	-53.1	10.4	0.0	2091.5

CASE 1

TABLE NO. 14

TIME	TIME	LTIME	LONGP	HEAT	BRATE	TEMP	PDOVE	SRNET	ORDET
LIFT-OFF									
0.00	0.000	28.447	-80.604	0.00	0.00	298.95	58.72	0.	2849934.
1.00	0.635	28.447	-80.604	0.00	0.00	298.92	58.89	0.	2848046.
2.00	1.277	28.447	-80.604	0.00	0.00	298.85	59.07	0.	2846482.
3.00	1.928	28.447	-80.604	0.00	0.00	298.74	59.25	0.	2845239.
4.00	2.586	28.447	-80.604	0.00	0.00	298.57	59.44	0.	2844316.
5.00	3.252	28.447	-80.604	0.00	0.00	298.36	59.64	0.	2843713.

Figure 19-19. Parameter Summary Table (Continued)

PARAMETER	TABLE	UNITS	DEFINITION
TIME	1	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
R	1	FEET	RADIUS FROM EARTH CENTER
ALT	1	FEET	ALTITUDE ABOVE REFERENCE ELLIPSOID
VSUBI	1	FEET/SEC	INERTIAL VELOCITY
GAMI	1	DEGREES	INERTIAL FLIGHT PATH ANGLE
AZI	1	DEGREES	INERTIAL AZIMUTH
GCLAT	1	DEGREES	GEOCENTRIC LATITUDE
GDLAT	1	DEGREES	GEODEIC LATITUDE
LONG	1	DEGREES	LONGITUDE
INCL	1	DEGREES	ORBITAL INCLINATION ANGLE
TIME	2	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
VSUBE	2	FEET/SEC	EARTH-FIXED VELOCITY
GAME	2	DEGREES	EARTH-FIXED FLIGHT PATH ANGLE
AZE	2	DEGREES	EARTH-FIXED AZIMUTH
VSUBR	2	FEET/SEC	WIND RELATIVE VELOCITY
GAMR	2	DEGREES	WIND RELATIVE FLIGHT PATH ANGLE
AZR	2	DEGREES	WIND RELATIVE AZIMUTH
VWIND	2	FEET/SEC	WIND VELOCITY
AZW	2	DEGREES	WIND AZIMUTH
RANGE	2	KILOMETERS	RELATIVE SURFACE RANGE
TIME	3	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
Z8-X	3	FEET	DOWNRANGE POSITION COMPONENT (INERTIAL)
Z8-Y	3	FEET	VERTICAL POSITION COMPONENT (INERTIAL)
Z8-Z	3	FEET	CROSSRANGE POSITION COMPONENT (INERTIAL)
ZD8-W	3	FEET/SEC	DOWNRANGE VELOCITY COMPONENT (INERTIAL)
ZD8-U	3	FEET/SEC	VERTICAL VELOCITY COMPONENT (INERTIAL)
ZD8-V	3	FEET/SEC	CROSSRANGE VELOCITY COMPONENT (INERTIAL)
AXACC	3	G'S	TOTAL AXIAL ACCELERATION
NRACC	3	G'S	TOTAL NORMAL ACCELERATION
LTACC	3	G'S	TOTAL LATERAL ACCELERATION
TIME	4	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
CHIP	4	DEGREES	PITCH ATTITUDE (INERTIAL)
CEIY	4	DEGREES	YAW ATTITUDE (INERTIAL)
CHIR	4	DEGREES	ROLL ATTITUDE (INERTIAL)
THERI	4	DEGREES	PITCH ANGLE IN BOOSTER REF SYSTEM
PSIRI	4	DEGREES	YAW (HEADING) ANGLE IN BOOSTER REF SYSTEM
PHIRI	4	DEGREES	ROLL ANGLE IN BOOSTER REF SYSTEM
DELPC	4	DEGREES	COMPOSITE PITCH GIMBAL ANGLE
DELYC	4	DEGREES	COMPOSITE YAW GIMBAL ANGLE
TIME	5	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION

Figure 19-19. Parameter Summary Table (Continued)

PARAMETER	TABLE	UNITS	DEFINITION
THMPS	5	POUNDS	MPS LOCAL THRUST
TAO	5	UNITLESS	MPS THROTTLE FACTOR
THSRM	5	POUNDS	SRM LOCAL THRUST
TELRM	5	POUNDS	LRM LOCAL THRUST
THOMS	5	POUNDS	OMS LOCAL THRUST
THRCS	5	POUNDS	RCS LOCAL THRUST
THRST	5	POUNDS	TOTAL LOCAL THRUST
TIME	6	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
THMPS	6	POUNDS	MPS LOCAL THRUST
TVMPS	6	POUNDS	MPS VACUUM THRUST
ISFMP	6	SECONDS	MPS SPECIFIC IMPULSE
WDMPS	6	LBS/SEC	MPS FLOWRATE
MPS F	6	POUNDS	MPS FUEL ONBOARD
MPS D	6	POUNDS	MPS FUEL SPENT
DPMPS	6	DEGREES	MPS PITCH GIMBAL ANGLE
DYMPS	6	DEGREES	MPS YAW GIMBAL ANGLE
TAO	6	UNITLESS	MPS THROTTLE FACTOR
TIME	7	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
THSRM	7	POUNDS	SRM LOCAL THRUST
TVSRM	7	POUNDS	SRM VACUUM THRUST
ISFSR	7	SECONDS	SRM SPECIFIC IMPULSE
WDSRM	7	LBS/SEC	SRM FLOWRATE
SRM F	7	POUNDS	SRM FUEL ONBOARD
SRM D	7	POUNDS	SRM FUEL SPENT
DSRM	7	DEGREES	SRM PITCH GIMBAL ANGLE
DYSRM	7	DEGREES	SRM YAW GIMBAL ANGLE
YRING	7	LBS/IN**2	Y RING PRESSURE
TIME	8	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
XHLB	8	POUNDS	TOTAL VEHICLE WEIGHT
XCG	8	INCHES	LONGITUDINAL CENTER OF GRAVITY LOCATION
ZCG	8	INCHES	VERTICAL CENTER OF GRAVITY LOCATION
MODE	8	DEGREES	DESCENDING NODE-MEASURED CCW FROM LAUNCH SITE
RNGAN	8	DEGREES	RANGE ANGLE
RHO	8	SLUGS/FT**3	ATMOSPHERIC DENSITY
REYN0	8	UNITLESS	REYNOLDS NUMBER
TIME	9	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
THOMS	9	POUNDS	OMS LOCAL THRUST
TVOMS	9	POUNDS	OMS VACUUM THRUST
ISFOM	9	SECONDS	OMS SPECIFIC IMPULSE
WDOMS	9	LBS/SEC	OMS FLOWRATE

Figure 19-19. Parameter Summary Table (Continued)

PARAMETER	TABLE	UNITS	DEFINITION
OMS F	9	POUNDS	OMS FUEL ONBOARD
OMS D	9	POUNDS	OMS FUEL SPENT
DPOMS	9	DEGREES	OMS PITCH GIMBAL ANGLE
DYOMS	9	DEGREES	OMS YAW GIMBAL ANGLE
TIME	10	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
TRCS	10	POUNDS	RCS LOCAL THRUST
TVRCS	10	POUNDS	RCS VACUUM THRUST
ISPRC	10	SECONDS	RCS SPECIFIC IMPULSE
WDRC	10	LBS/SEC	RCS FLOWRATE
RCS F	10	POUNDS	RCS FUEL ONBOARD
RCS D	10	POUNDS	RCS FUEL SPENT
DRCS	10	DEGREES	RCS PITCH GIMBAL ANGLE
DYRCS	10	DEGREES	RCS YAW GIMBAL ANGLE
TIME	11	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
MACH	11	UNITLESS	MACH NUMBER
ALPHA	11	DEGREES	PITCH ANGLE OF ATTACK
BETA	11	DEGREES	SIDESLIP ANGLE
Q	11	LBS/FT**2	DYNAMIC PRESSURE
QALPH	11	LB-DEG/FT**2	Q * ANGLE OF ATTACK
QBETA	11	LB-DEG/FT**2	Q * SIDESLIP ANGLE
ENMACH	11	UNITLESS	EARTH-RELATIVE MACH NUMBER
INBD	11	DEGREES	INBOARD ELEVON ANGLE
OUTBD	11	DEGREES	OUTBOARD ELEVON ANGLE
TIME	12	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
CH VL	12	FEET/SEC	CHARACTERISTIC VELOCITY
ID VL	12	FEET/SEC	IDEAL VELOCITY
TR L	12	FEET/SEC	TURNING LOSSES
GV L	12	FEET/SEC	GRAVITY LOSSES
DR L	12	FEET/SEC	DRAG LOSSES
BKP L	12	FEET/SEC	BACKPRESSURE LOSSES
GIM L	12	FEET/SEC	GIMBAL LOSSES
TIME	13	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
FAA	13	POUNDS	AXIAL AERODYNAMIC FORCE
FAB	13	POUNDS	AXIAL BASE FORCE
DRAG	13	POUNDS	AERODYNAMIC DRAG
FAN	13	POUNDS	NORMAL AERODYNAMIC FORCE
FNB	13	POUNDS	NORMAL BASE FORCE
LIFT	13	POUNDS	AERODYNAMIC LIFT
FAS	13	POUNDS	SIDE AERODYNAMIC FORCE
FMB	13	FOOT-POUND	BASE PITCHING MOMENT

Figure 19-19. Parameter Summary Table (Continued)

PARAMETER	TABLE	UNITS	DEFINITION
PRESS	13	LBS/FT**2	ATMOSPHERIC PRESSURE
TIME	14	SECONDS	INSTANTANEOUS TIME FROM SRB IGNITION
TIME	14	SECONDS	TIME TO VACUUM IMPACT POINT
LTIMP	14	DEGREES	LATITUDE OF VACUUM IMPACT POINT
LONGMP	14	DEGREES	LONGITUDE OF VACUUM IMPACT POINT
HEAT	14	BTU	STAGNATION HEATING INDICATOR
HEATE	14	BTU/SEC	STAGNATION HEATING RATE
TEMP	14	KELVIN	ATMOSPHERIC TEMPERATURE
PDOME	14	LBS/IN**2	LOX BULKHEAD PRESSURE INDICATOR
SRMET	14	POUNDS	SRM-ET SHEAR LOAD INDICATOR
ORBET	14	POUNDS	ORBITER-ET ATTACH LOAD INDICATOR

Figure 19-19. Parameter Summary Table (Concluded)

1.5 STAGE 6/2 EO, MISSION 2 - 10 FT STRETCH										
Tables of Tank Height, Propellant Mass, Total Thrust and Flowrate										
Time (sec)	Acel (G's)	LOX Level (inches)	LOX Mass (pounds)	Fuel Level (inches)	Fuel Mass (pounds)	Flowrate (lbs/sec)	Vac Thrust (pounds)	Propellant (pounds)	Inlet Pres (lbs/inch ²)	
0.000	1.3571	503.08	148417.34	1215.38	247543.20	7584.60	3250000.00	1750091.00	0.00	
1.000	1.3623	503.08	1477908.12	1215.38	246467.83	7584.60	3250000.00	1742506.40	0.00	
2.000	1.3675	492.10	1471398.89	1192.36	245392.46	7584.60	3250000.00	1734921.81	0.00	
3.000	1.3729	483.97	1464889.66	1180.28	244317.09	7584.60	3250000.00	1727337.21	0.00	
4.000	1.3784	478.19	1458380.44	1171.02	243241.72	7584.60	3250000.00	1719752.61	0.00	
5.000	1.3840	473.40	1451871.21	1162.92	242166.34	7584.60	3250000.00	1712168.01	0.00	
6.000	1.3897	469.14	1445361.99	1156.00	241090.97	7584.60	3250000.00	1704583.42	0.00	
7.000	1.3956	465.46	1438852.76	1149.36	240015.60	7584.60	3250000.00	1696998.82	0.00	
8.000	1.4016	461.95	1432343.53	1143.25	238940.23	7584.60	3250000.00	1689414.22	0.00	
9.000	1.4077	458.70	1425834.31	1137.34	237864.86	7584.60	3250000.00	1681829.62	0.00	
10.000	1.4140	455.62	1419325.08	1131.74	236789.49	7584.60	3250000.00	1674245.03	0.00	
11.000	1.4204	452.69	1412815.86	1126.23	235714.12	7584.60	3250000.00	1666660.43	0.00	
12.000	1.4269	449.87	1406306.63	1120.97	234638.74	7584.60	3250000.00	1659075.83	0.00	
13.000	1.4335	447.18	1399797.40	1115.71	233563.37	7584.60	3250000.00	1651491.23	0.00	
14.000	1.4402	444.53	1393288.18	1110.65	232488.00	7584.60	3250000.00	1643906.64	0.00	
15.000	1.4471	442.03	1386778.95	1105.59	231412.63	7584.60	3250000.00	1636322.04	0.00	
16.000	1.4541	439.52	1380269.73	1100.60	230337.26	7584.60	3250000.00	1628737.44	0.00	
17.000	1.4612	437.14	1373760.50	1095.63	229261.89	7584.60	3250000.00	1621152.84	0.00	
18.000	1.4685	434.79	1367251.28	1090.68	228186.51	7584.60	3250000.00	1613568.25	0.00	
19.000	1.4759	432.47	1360742.05	1085.73	227111.14	7584.60	3250000.00	1605983.65	0.00	
20.000	1.4834	430.23	1354232.82	1080.78	226035.77	7584.60	3250000.00	1598399.05	0.00	
21.000	1.4910	428.00	1347723.60	1075.84	224960.40	7584.60	3250000.00	1590814.45	0.00	
22.000	1.4987	425.82	1341214.37	1070.89	223885.03	7584.60	3250000.00	1583229.86	0.00	
23.000	1.5065	423.68	1334705.15	1065.95	222809.66	7584.60	3250000.00	1575645.26	0.00	
24.000	1.5145	421.55	1328195.92	1061.00	221734.29	7584.60	3250000.00	1568060.66	0.00	
25.000	1.5225	419.47	1321686.69	1056.05	220658.91	7584.60	3250000.00	1560476.06	0.00	
26.000	1.5307	417.41	1315177.47	1051.11	219583.54	7584.60	3250000.00	1552891.47	0.00	
27.000	1.5389	415.35	1308668.24	1046.16	218508.17	7584.60	3250000.00	1545306.87	0.00	
28.000	1.5472	413.35	1302159.02	1041.22	217432.80	7584.60	3250000.00	1537722.27	0.00	
29.000	1.5556	411.35	1295649.79	1036.27	216357.43	7584.60	3250000.00	1530137.67	0.00	
30.000	1.5641	409.35	1289140.56	1031.31	215282.06	7584.60	3250000.00	1522553.08	0.00	
31.000	1.5727	407.40	1282631.34	1026.38	214206.68	7584.60	3250000.00	1514968.48	0.00	
32.000	1.5813	405.45	1276122.11	1021.43	213131.31	7584.60	3250000.00	1507383.88	0.00	
33.000	1.5900	403.50	1269612.89	1016.49	212055.94	7584.60	3250000.00	1499799.28	0.00	
34.000	1.5987	401.58	1263103.66	1011.54	210980.57	7584.60	3250000.00	1492214.69	0.00	
35.000	1.6075	399.67	1256594.43	1006.60	209905.20	7584.60	3250000.00	1484630.09	0.00	
36.000	1.6164	397.76	1250085.21	1001.65	208829.83	7584.60	3250000.00	1477045.49	0.00	
37.000	1.6254	395.87	1243575.98	996.70	207754.46	7584.60	3250000.00	1469460.89	0.00	
38.000	1.6343	393.98	1237066.76	991.76	206679.08	7584.60	3250000.00	1461876.30	0.00	
39.000	1.6433	392.10	1230557.53	986.81	205603.71	7584.60	3250000.00	1454291.70	0.00	
40.000	1.6524	390.23	1224048.31	981.87	204528.34	7584.60	3250000.00	1446707.10	0.00	
41.000	1.6615	388.36	1217539.08	976.92	203452.97	7584.60	3250000.00	1439122.50	0.00	
42.000	1.6708	386.49	1211029.85	971.97	202377.60	7584.60	3250000.00	1431537.91	0.00	
43.000	1.6804	384.63	1204520.63	967.03	201302.23	7584.60	3250000.00	1423953.31	0.00	
44.000	1.6901	382.77	1198011.40	962.08	200226.85	7584.60	3250000.00	1416368.71	0.00	
45.000	1.7000	380.92	1191502.18	957.14	199151.48	7584.60	3250000.00	1408784.12	0.00	
46.000	1.7100	379.06	1184992.95	952.19	198076.11	7584.60	3250000.00	1401199.52	0.00	
47.000	1.7200	377.20	1178483.72	947.25	197000.74	7584.60	3250000.00	1393614.92	0.00	
48.000	1.7300	375.35	1171974.50	942.30	195925.37	7584.60	3250000.00	1386030.32	0.00	
49.000	1.7398	373.49	1165465.27	937.35	194850.00	7584.60	3250000.00	1378445.73	0.00	
50.000	1.7490	371.64	1158956.05	932.41	193774.63	7584.60	3250000.00	1370861.13	0.00	
51.000	1.7575	369.78	1152446.82	927.46	192699.25	7584.60	3250000.00	1363276.53	0.00	
52.000	1.7654	367.93	1145937.59	922.52	191623.88	7584.60	3250000.00	1355691.93	0.00	
53.000	1.7723	366.07	1139428.37	917.57	190548.51	7584.60	3250000.00	1348107.34	0.00	
54.000	1.7778	364.21	1132919.14	912.62	189473.14	7584.60	3250000.00	1340522.74	0.00	
55.000	1.7818	362.36	1126409.92	907.68	188397.77	7584.60	3250000.00	1332938.14	0.00	
56.000	1.7844	360.50	1119900.69	902.73	187322.40	7584.60	3250000.00	1325353.54	0.00	
57.000	1.7865	358.65	1113391.46	897.79	186247.03	7584.60	3250000.00	1317768.95	0.00	
58.000	1.7895	356.79	1106882.24	892.84	185171.65	7584.60	3250000.00	1310184.35	0.00	
59.000	1.7932	354.94	1100373.01	887.90	184096.28	7584.60	3250000.00	1302599.75	0.00	
60.000	1.8033	353.08	1093863.79	882.95	183020.91	7584.60	3250000.00	1295015.15	0.00	
61.000	1.8208	351.22	1087354.56	878.00	181945.54	7584.60	3250000.00	1287430.56	0.00	

Figure 19-20. Propulsion Output Table

Table 19-7. Propulsion Output Table Parameters

Variable	Description	Units
Time	Time from lift-off	s
Acel	Axial acceleration	g's
LOX Level	Level of LOX in tank	in.
LOX Mass	Mass of LOX in tank	lbm
Fuel Level	Level of LH2 in tank	in.
Fuel Mass	Mass of LH2 in tank	lbm
Vac Thrust	MPS vacuum thrust	lbf
Propellant	Total onboard MPS propellant mass	lbm
Inlet Pres	Inlet pressure	lbf/in. ²

APPENDIX A. USER INTERFACE FOR MASS PROPERTIES PROGRAM

A.1 INTRODUCTION

This Appendix outlines the use of the special User Interface Program used with the Mass Properties Program that was developed for the MASTRE Program. The Mass Properties Program is a stand-alone, menu-driven VAX/VMS input/output interface program. This program was created to provide data to the MASTRE Program such that mass properties calculations can be performed in a dynamic fashion. The purpose of the Mass Properties Program is to replace the previous mass properties methodology, which was based on the interpolation of axial and normal CG as a function of weight overboard. The previous methodology introduced errors into the code due to variable staging times and event sequences. Additional information about the methodology and equations used in the Mass Properties Program are discussed in the MASTRE Engineering Manual.

In general, each vehicle may be thought of as being composed of modules. A module will be created for inert payloads, solid motors, nonthrottleable liquid engines, throttleable liquid engines, or hybrid (solid/liquid) motors. Once created, individual modules are connected to specify the overall vehicle. Also, previously created modules can be used in other vehicle configurations by reconnecting them. Therefore, once a library of modules has been created, many different vehicles may be implemented.

The modularity of the program is demonstrated in *Figure A-1*. In this figure, the Redesigned Solid-Rocket Motor (RSRM) module was created using the Solid Motor Module, and the 1.5 Stage Common Core was created using the throttleable engine module. Each module is created in a local coordinate system that, in this case, was located at the nose of the module. This particular location is not mandatory as the user may choose any reference location. Once the modules are created, they can be connected by specifying their locations in a global coordinate system. The global coordinate system shown in *Figure A-1* is the National Launch System (NLS) coordinate system, which is 2,000 in. in front of the previous Space Shuttle system.

Once a vehicle is created and configured using the program, it can be accessed by the MASTRE Program by specifying the use of the alternate mass properties in the User Interface Program (see Section 15) and placing the name of the vehicle file into the MASTRE command file. The reference locations of the global coordinate system must also be input.

The Mass Properties Program is activated by the user typing the command "RUN CG" and utilizing the many menu options available to him. *Figure A-2* shows the first menu that appears when the Mass Properties module is initiated. As can be seen in this figure, Inert Payloads, Solid Motors,

Nonthrotttable Engines, Throtttable Engines, Hybrid Motors, and Merge Module are optional items on the menu. Each of the motor dependent items may be entered to create a module.

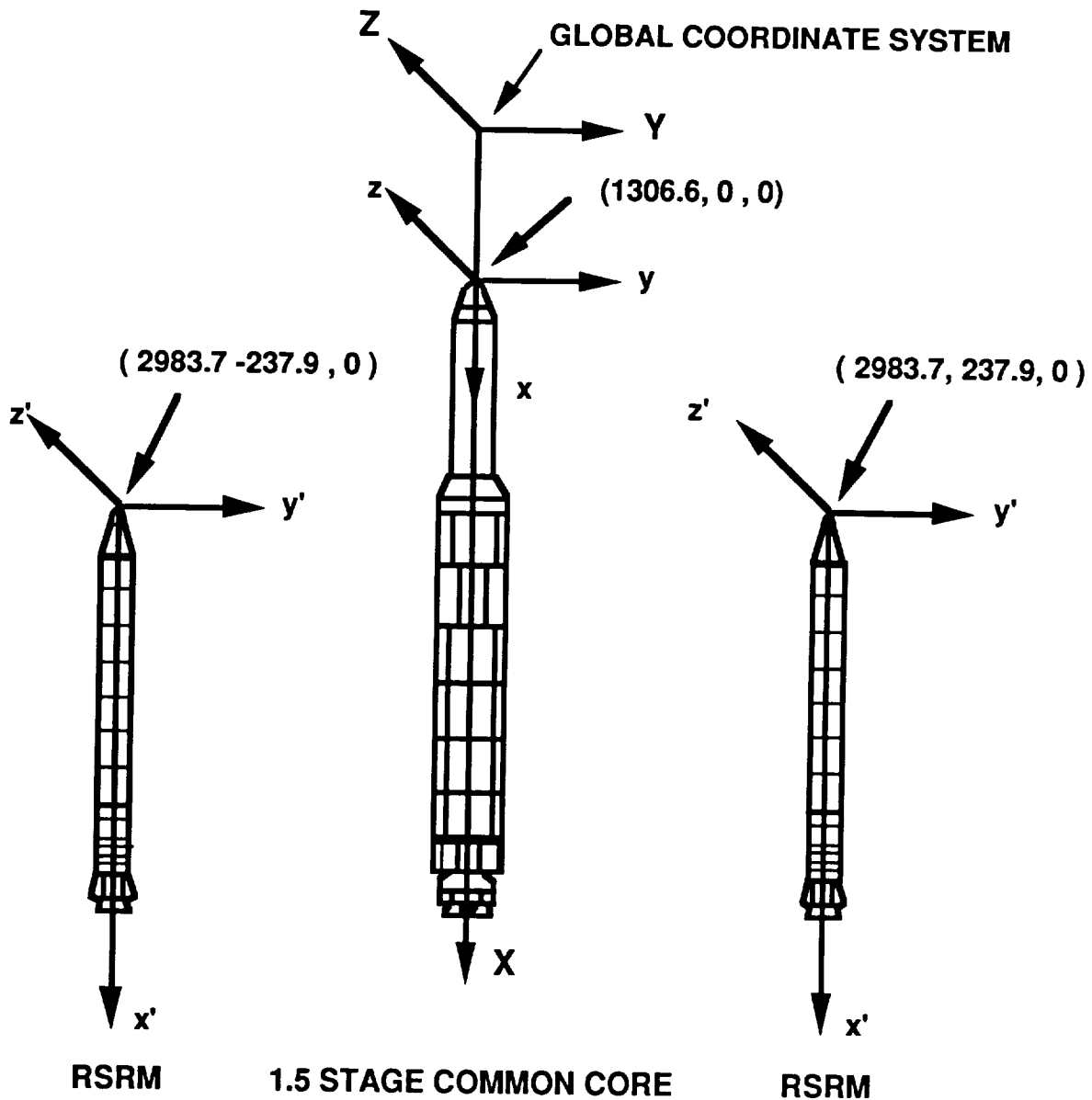


Figure A-1 . Example Vehicle Configuration

The Merge Module option displayed in the menu is the overall vehicle creation module. This option is used once all of the modules for a vehicle configuration have been created. The modules are connected in the Merge Module to form an overall vehicle coordinate system. Units used in the Mass

Properties Program are inches for measurements and pounds mass for mass. The headings on the data tables within the program provide unit requirements for the user.

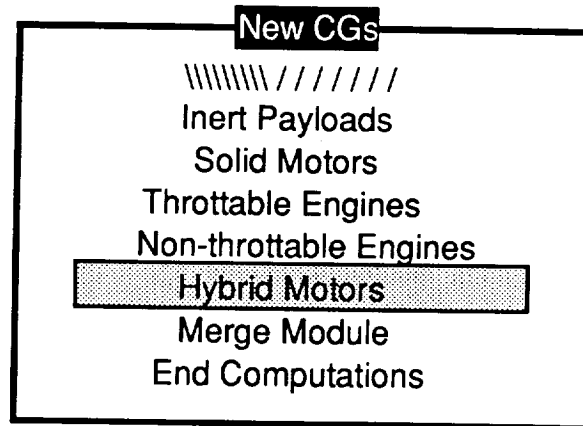


Figure A-2. New CGs or Main Menu

A.2 KEYPAD OPERATIONS

All of the input/output operations in the mass properties User Interface Program are made using the operations keypad. The keypad layout is shown in **Figure A-3**. Keypad operations defined in Section 3 are the same in the Mass Properties Program and will be summarized here.

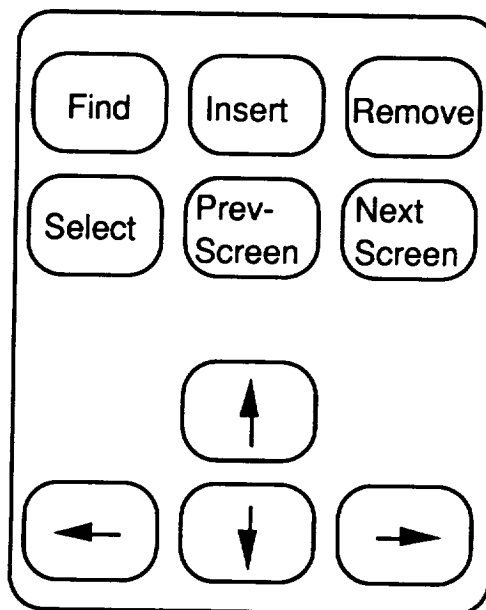


Figure A-3. VT 220 Keypad Definition

When in the edit mode, the Insert Here Key allows the user to insert a new data entry line above a data item that is high-lighted; the Remove Key allows the user to delete the data entry line

that is currently high-lighted; the Select Key allows the user to make an entry into the position that is currently high-lighted; and the Prev Scrn and Next Scrn keys allow the user to switch between screens. The Find key is not used with the Mass Properties Program. After these data have been entered for the current screen, or screens, pressing the Return Key will move the user to the next screen.

Several features have been built into the input/output editor. If the user makes a mistake entering data incompatible with the currently high-lighted field, the program will display the previous value in the field. Also, if the user mistakenly presses the Select Key or forgets what the previous value of a selected field was, pressing the Return Key before any entries are made will restore the previous value of the field.

A.3 INERT PAYLOADS MODULE

The inert payloads module compiles and computes the CG for all of the inert components. This module was created with the intention that any excess inert components (those not in a solid-motor, nonthrotttable engine, throtttable engine, or hybrid engine module) would be inserted in this module. The inert components of an engine or motor are grouped with the liquid or grain data for modularity reasons.

Inert components entered into this module can be referenced to any local coordinate system. However, it is advisable to use something that could be easily transported to other configurations. For the 1.5 Stage Vehicle shown in **Figure A-1**, the tip of the nose was used as a local reference point, and then referenced to the overall coordinate system.

A flow chart of the user interface requirements for use of the Inert Payloads Module is shown in **Figure A-4**. The first screen, after selecting "Inert Payloads" from the "New CGs" screen, offers the user the choice of selecting from existing files, creating a new file, or returning to the overall selection menu. The user selects the existing files choice in case a file needs to be updated, examined, or used as the basis for a new file. Selection of this option will display all of the current data files that have the ".IPI" extension, which is the next block shown. All input files to the module have a ".IPI" extension, and all output files to the module have a ".IPM" extension. The user may then select which file to open. The new file choice requires completely starting from the beginning to create a new file.

The next screen contains the input and output section for the inert components. Each part is entered with its name, axial CG location, lateral CG location, normal CG locations, and mass. The CG locations of the inert components are referenced to the local coordinate system that the user chooses. **Figure A-5** shows example inert components referenced to a local coordinate system. The operations of adding a new part, deleting a part, and modifying data are accessed using the function

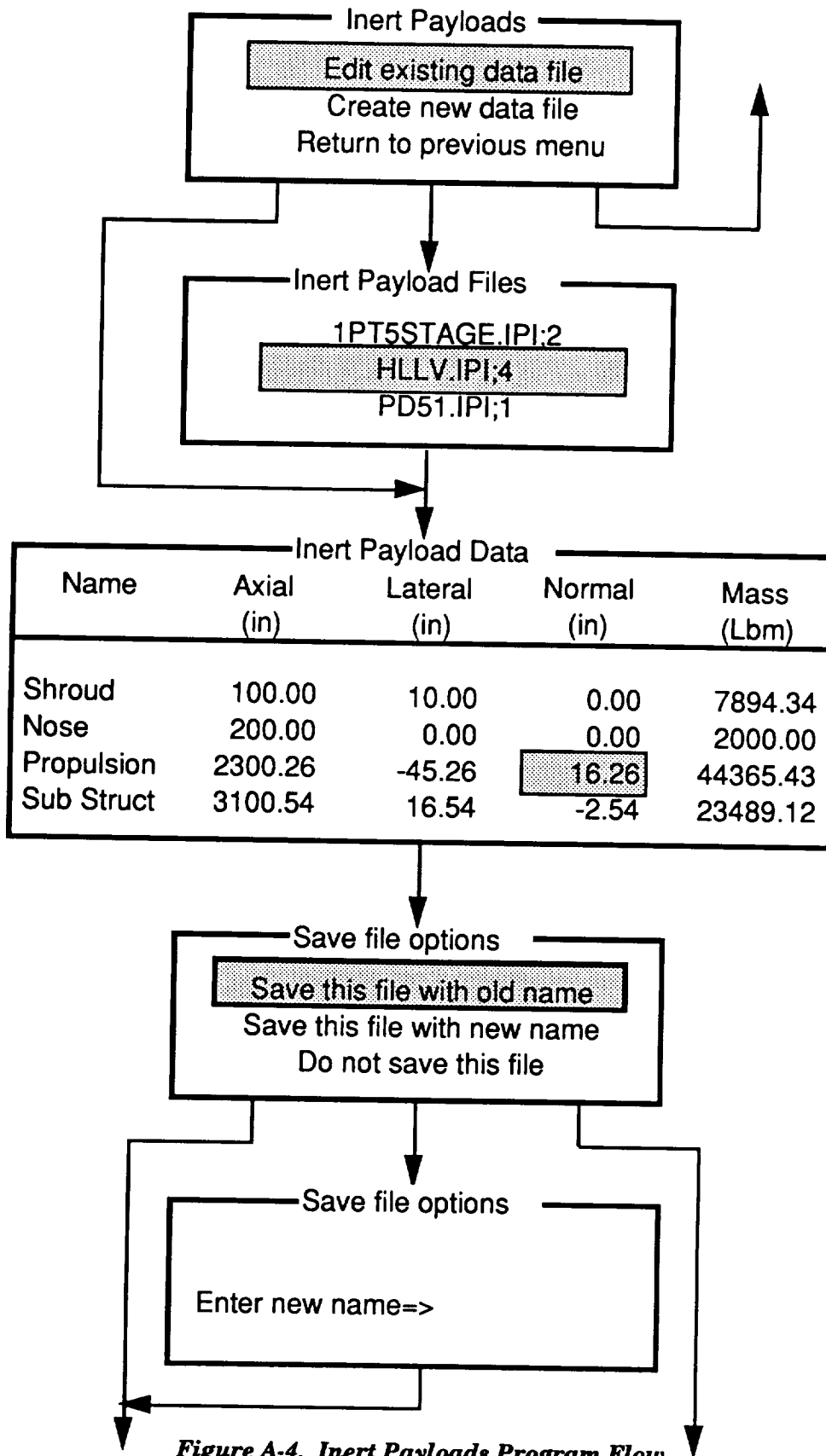


Figure A-4. Inert Payloads Program Flow

keys. Once all of the changes have been made to the data, the Return Key will send the user to the "save selections".

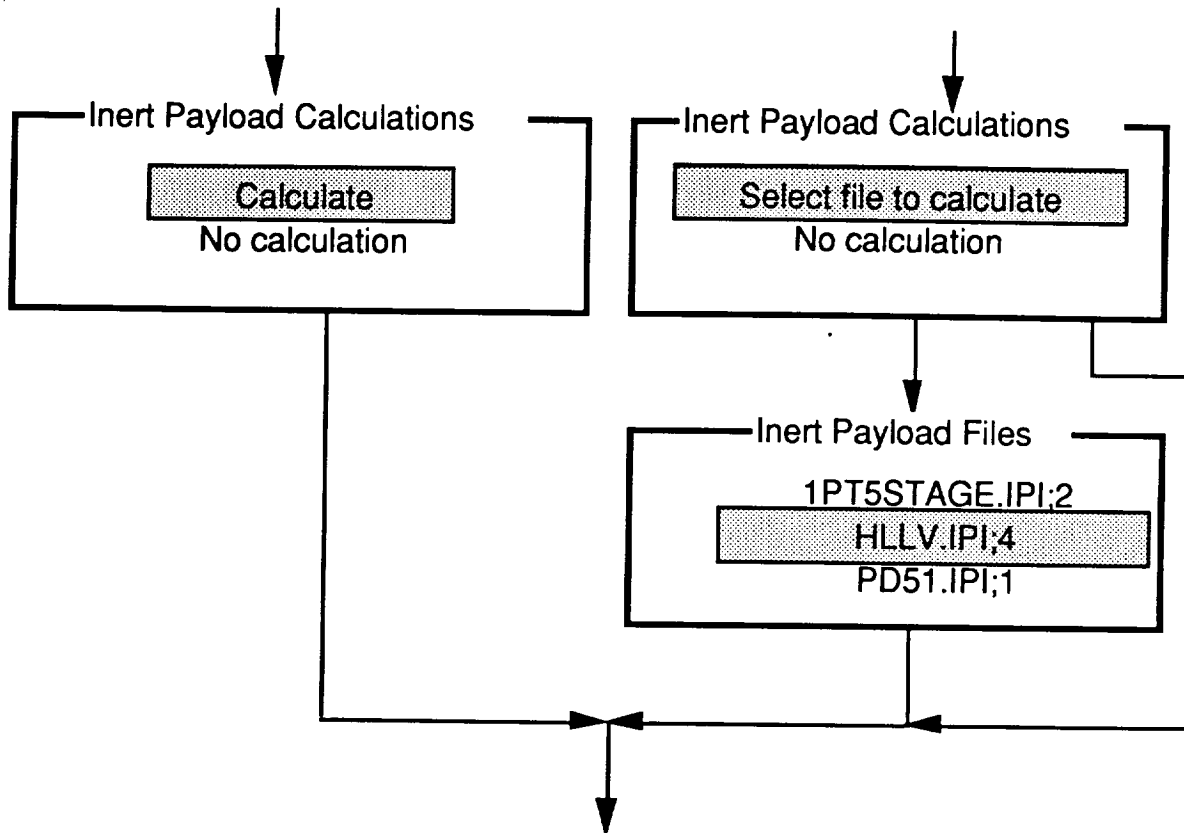


Figure A-4. Inert Payloads Program Flow

The next screen displayed allows the user to save the data just entered with the old file name (if it is not a new file), to save the data with a new file name, or not to save the data. If the old file name option is selected, the modified data will be written over the old file with that name, and the old file data will be lost. If the new file name option is selected, the user will be requested to input the file name where the data are to be saved. If a previously used file name is entered, the file will be written to the name, but a new version number will be assigned. Any previous files with that name will not be modified.

After selections for file saving have been completed, calculation options will be displayed. If no calculations are required, the user is returned to the main menu. If calculations are required, an input file is required. An input file that has been saved previously does not have to be reformulated. If the data formulated in the first part of the module were not saved, the user is required to select another input file to use for the calculation of the mass properties data. If this option is selected, all of

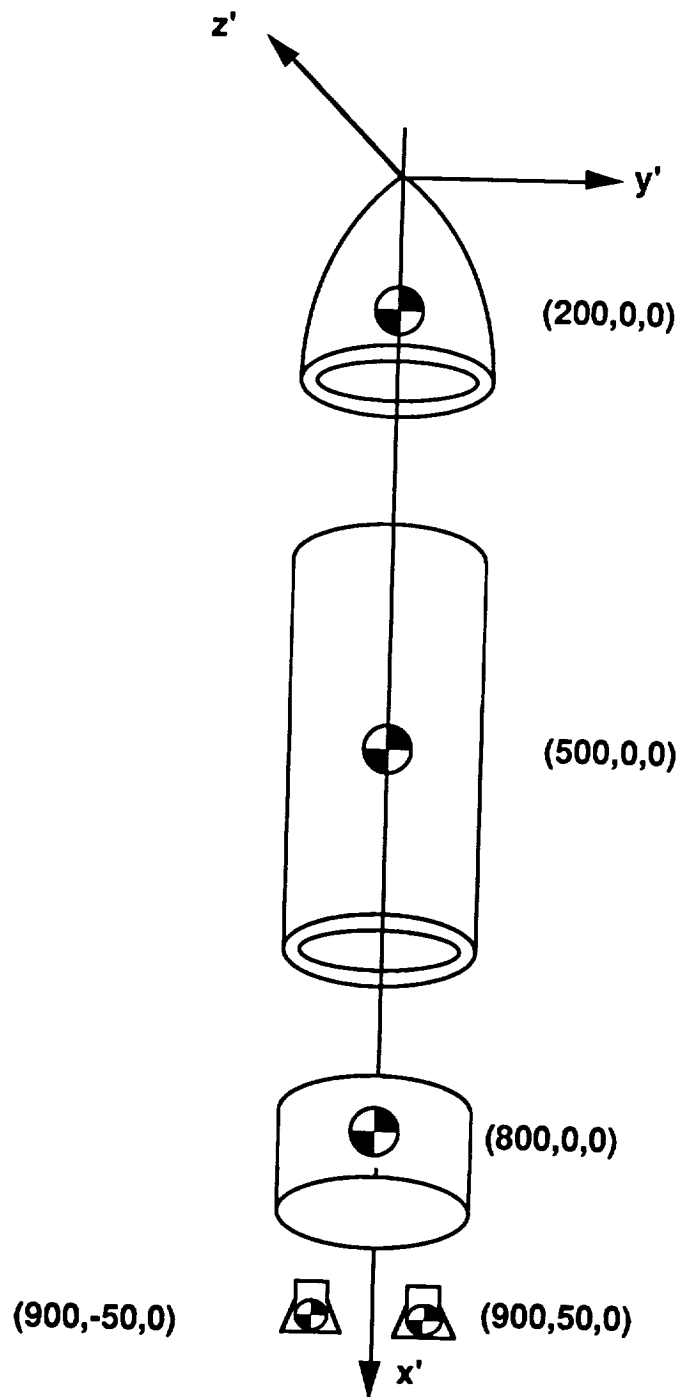


Figure A-5. Example Inert Components

the current input files are displayed for the user. After these operations, the user is returned to the main menu.

A.4 SOLID MOTOR MODULE

The Solid-Motor Module is composed of the solid grain, casing, and inert components that are used for a solid motor. The base calculation code for this module is the Solid-Rocket Motor Design Optimization Program (SRMDOP), which is documented in Reference 1. This program has been subjugated to the Mass Properties Program while still retaining its useful features. The module uses the user-defined grain shape and computes the regression rates of the grain versus time. The grain shapes that can be implemented are circular perforated, standard star, truncated star, wagon wheel, and tabular data. After computing the regression rates, the Solid-Motor Module calculates the CG location versus mass overboard.

The Solid-Motor Module can be used to maximize total impulse to motor weight, minimize motor weight, or to match a thrust versus time history. For most of the applications foreseen, matching the thrust trace should be the appropriate choice. When using any of the above options, the user may choose from 17 parameters to optimize the requirements.

To access the program, "Solid Motors" is selected from the "New CGs" menu. The first options let the user choose an old data file to build on (see **Figure A-6**). The user is not allowed to start without data because of the complexity and the amount of inputs.

Once an old data file has been selected, the user is presented with the "Menu" screen. This screen has all of the options for the various editing screens for the solid motor inputs. Each screen may be edited one at a time by high-lighting and selecting the screen. Upon return from a section, the high-light bar will remain on the section that was just edited, so that the user will know what section was just edited. Any or all of the sections may be edited. When editing is complete, the return option is selected, and the file may be saved and mass properties calculated.

The first option in the solid motor menu is to modify the inert parts. The inert parts are all of the inerts that are unique to a solid motor. The name, mass, and reference location of the inert components are entered here. The inert components are limited to 100. Also, their reference location is referenced to the local motor coordinate system. The inerts shown in **Figure A-7** are taken from the RSRM and are referenced to the tip of the nose of the motor. The reference system for this system is shown in **Figure A-8**.

The next 13 input/edit screens shown in **Figure A-9 through A-21** will be discussed in a tabular format. All of the screens present data used in constructing the RSRM simulation. Many of the definitions used in the descriptions of these data have been extracted from Reference 1.

Solid Motor Inert Payload Data				
Name	Axial (in)	Lateral (in)	Normal (in)	Mass (Lbm)
BODY STRUCTURE	1264.94	-5.24	2.01	28474.90
INV ENVI PROTEC	1563.73	-7.97	8.23	1676.80
SEP AND RECOVER	438.70	-2.52	7.97	10369.80
PRIME POWER	488.50	-52.00	-39.00	90.00
ELECT AND INSTR	1155.06	27.31	27.58	1182.60
TVC SYS	1889.51	64.11	-0.31	2328.00
RANGE SAFETY	730.94	58.19	-0.65	144.40
FWD S CASE	665.58	0.00	-0.01	26211.67
FWD S INSULATIO	658.67	0.00	0.00	4511.67

Figure A-7. Solid Module Inert Component Menu

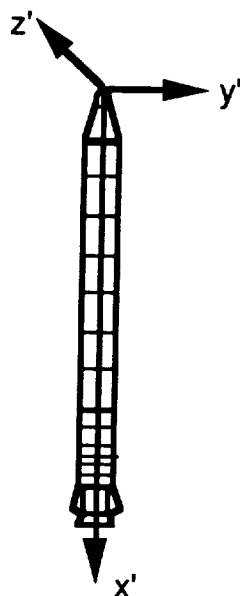


Figure A-8. Solid-Motor Coordinate System

Optimization Parameters

Indicate which parameters are to be optimized
1 => Optimize parameter 0 => Parameter remains fixed
Use up/down arrow keys to move, Select key to cycle

0	Initial throat diameter
1	Nozzle exit diameter
1	Nozzle exit half angle
<input checked="" type="checkbox"/>	Axial cp grain length at nozzle end having addit. taper
0	Difference in cp web thickness for axial length above
0	Difference in cp web thickness at head & aft ends
0	Average internal diameter of cp portion of grain
0	Burning rate coefficient below transition pressure
0	Angle nozzle end of cp grain makes with motor axis
0	Initial total length of the cp grain
0	Initial slant length of cp grain at nozzle end
0	Initial total length of star shaped grain
1	Fillet radius for star shaped grain
0	Web thickness of truncated star segment of grain
0	Web thickness of standard star segment of grain
0	Web thickness of wagon wheel segment of grain
0	Cusp radius for standard star in inches

Figure A-9. Solid Module Optimization Parameter Menu

Program Control Inputs

155.00	Max allowable nozzle exit diameter (in)
3	Type of optimization procedure to use
10.00	Min allowable limit of nozzle exit half angle (deg)
20.00	Max allowable limit of nozzle exit half angle (deg)
0.10	Min allowable limit of throat-to-port area ratio
0.50	Max allowable limit of throat-to-port area ratio
0.035	Min allowable limit of burning rate coef (in/s)
0.040	Max allowable limit of burning rate coef (in/s)
0.00	Min allowable limit of star grn fillet radius (in)
2.00	Max allowable limit of star grn fillet radius (in)
0.60	Min allowable limit for $1-DI/DO$ for cp grain only
0.60	Max allowable limit for $1-DI/DO$ for cp grain only
8.00	Min allowable limit of star grn web thickness (in)
9.00	Max allowable limit of star grn web thickness (in)
0.00	Min required ideal velocity (ft/sec)
1.00	Initial stepsize for pattern search procedure
1.00	Min allowed of initial step size
1.00	Max number of pattern moves before search is terminated
1	Controls amount of data output during search
2	Option for output of initial & final motor traces
F	Flg for output of input thrust profile to Thrust.Inp
F	Flg for output of output thrust profile to Thrust.Out
F	Flg for output of detailed mass properties
T	Flg indicating whether BARF effects included

Figure A-10. Solid Module Program Control Input Menu

Basic Propellant Characteristics

Use up/down arrow keys to move - Select to change values

Return to go back to main solid menu

1.20	Ratio of burning rate exp above & below transition press
0.064	Density of the propellant (Lbm/in ³)
0.03918	Burning rate coef below transition pressure
0.35	Burning rate exponent below transition pressure
0.00	Alpha - constant in flame ht. erosive burning model
1.00	Beta - constant in flame ht. erosive burning model
0.2E-07	Viscosity of the propellant gases
5162.0	Input characteristic exhaust velocity (ft/sec)

Figure A-11. Solid Module Propellant Characteristics

Basic Motor Dimensions

Use up/down arrow keys to move - Select to change values

Return to go back to main solid menu

1332.00	Estimated total grain length (in)
41.40	Average web thickness for controlling grain (in)
149.644	Nozzle exit diameter (in) [DE]
53.85	Initial throat diameter (in) [DTI]
0.00	Nozzle cant angle wrt longitudinal motor axis (deg)
12.00	Nozzle half angle (deg) [ALFAN]
217.88	Length of grain with taper not represented by Z0 (in) [LTAP]
9.664	Difference in web thickness assoc with LTAP (in) [XT]
3.18	Difference in web thickness for controlling grain (in) [Z0]
0.38E-04	Temp sensitivity of CSTAR at constant pressure
10000.0	Transition press for switching N1 to N2 & A1 to A2 (lbf/in ²)
0.00	Axial dist to top center of grn from sol mot ref loc (in)
0.00	Lateral dist to top center of grn from solid mot ref loc (in)
0.00	Normal dist to top center of grn from solid mot ref loc (in)

Figure A-12. Solid Module Motor Dimensions Menu

Basic Performance Constants

Use up/down arrow keys to move - Select to change values
Return to go back to main solid menu

0.04	Desired burn increment during tailoff (in)
1000.00	Distance burned at which propellant breakup occurs (in)
10000.0	Depress rate where propellant extinguishes (Lbf/in ³)
0.98	Thrust loss coefficient
122.000	Estimated burn time (s)
130000.0	Height of burnout (feet)
1.20	Ratio of specific heats of propellant gases
0.00947	Reference throat erosion rate (in/s)
60.00	Grain temperature (F)
625.00	Reference nozzle stagnation pressure
53.8	Reference throat diameter
0.0015	Temperature sensitivity coef of press at constant K
60.0	Reference temperature of grain (F)
1.445	Effective gamma at nozzle exit plane
0.0	Pressure for extinguishing propellant (Lbf/in ²)
14.7	Initial atmospheric pressure (Lbf/in ²)

Figure A-13. Solid Module Performance Constants Menu

Basic Configuration & Arrangement

Use up/down arrow keys to move - Select to change values
Return to go back to main solid menu

0.00	Number of termination ports (0 for none)
3	Input type
3	Grain type
1	Star type
1	Star and cp configuration
1	Cp grain end configuration
5	Number of tabular inputs (0 for no tabular input)

Figure A-14. Solid Module Grain Configuration and Arrangement Menu

Tabular Values

Use up/down arrow keys to move - Select to change values -
Prev/Next Scr for other tables - Return to go back to main solid menu

0.00	Distance burned (in)
30106.0	Burning area in the port (in ²)
0.00000	Burning area in the slots (in ²)
0.00	Burning area in nozzle end (in ²)
0.00	Port area at head end (in ²)
0.00	Port area at nozzle end (in ²)
0.0	Initial vol of chamber gases assoc w/tab input (in ³)
27380.0	Mass of tabular burn inputs left at distance burned (Lbm)
-4.5	Cg of tabular burn inputs left at distance burned (in)

tabular value set
tabular val # 1

Figure A-15. Solid Module Tabular Input Menu

Basic Geometry for CP Grain

Use up/down arrow keys to move - Select to change values -
Nxt Scr for upper/lower scrns - Return to go back to main solid menu

143.4	Average initial outside diameter (in)
60.5	Average initial inside radius (in)
3.00000	Number of flat burning slot sides (excluding end)
8.72	Angle nozzle end of grain make w/ motor axis (deg)
1103.20	Initial length of cp grain (in)
72.33	Init slant length of burning conical grain - nozzle end (in)
0.0	Contraction angle at nozzle end (deg)
90.0	Contraction angle at head end (deg)
2.0	Beginning slot widths (in)

CP Geometry Arrays

156.47	639.80	959.69	0.00	0.00
0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00
T	T	T	T	T
T	F	F	T	T

Figure A-16. Solid Module CP Grain Geometry Menu

Basic Geometry for Star Grain

Use up/down arrow keys to move - Select to change values-
Nxt Scr for upper/lower scrns - Return to go back to main solid menu

0. Number of flat burning slot side (not incl. nozzle end)
156.47 Initial length of star shaped perforate grain (in)
11. Number of star points
72.0 Average star grain outside radius (in)
1.79 Fillet radius (in)
0. Number of star nozzle end burning surfaces
0.00 Initial width of the slots (in)

Star Geometry Arrays

0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00
0	0	0	0	0
T	T	T	T	T
T	T	T	T	T

Figure A-17. Solid Module Star Grain Geometry Menu

Geometry for Standard Star

Use up/down arrow keys to move - Select to change values
Return to go back to main solid menu

0.00 Angle location of the fillet center (deg)
32.80 Angle of star point (deg)
9.00 Web thickness of the grain (in)
0.00 Star grain cusp radius (in)

Figure A-18. Solid Module Standard Star Geometry

Thrust vs. Time Data

Use up/down arrow keys to move - Select to change values
Return to go on

8 Number of thrust-vs-time data points (20 max)
0.10e-07 Reduces magnitude of pattern search objective function

Time/Thrust/Weight Arrays

1.00	3200000.00	1.00
6.00	3400000.00	1.00
20.00	3400000.00	1.00
50.00	2275000.00	1.00
80.00	2550000.00	1.00
106.00	1800000.00	1.00
117.00	300000.00	1.00
122.00	100.00	1.00

Figure A-19. Solid Module Thrust History Input Menu

Geometry for Wagon Wheel

Use up/down arrow keys to move - Select to change values
Return to go back to main solid menu

0.00 Thickness of the propellant web (in)
0.00 Length of parallel sides of 2 sets of star pts (in)
0.00 Length of parallel sides of 2 sets of star pts (in)
0.00 Angles between slant sides of star pts (deg)
0.00 Angles between slant sides of star pts (deg)
0.00 Half widths of star points (in)

Figure A-20. Solid Module Wagon Wheel Geometry Menu

Geometry for Truncated Star

Use up/down arrow keys to move - Select to change values
Return to go back to main solid menu

0.00 Initial radius of the truncation (in)
0.00 Thickness of propellant web at bottom of slot (in)

Figure A-21. Solid Module Truncated Star Geometry Menu

A.4.1 Optimization Parameters

The optimization parameter menu, as shown in *Figure A-9*, allows the user to choose the parameters that will be modified to achieve the optimization that will be requested in the Program Control Inputs menu. Any or all of the parameters may be optimized when trying to match a optimization type. However, specifying more parameters takes more computer time to perform the search. It would seem advisable to limit the number of optimizations to the parameters that the user was most unsure so that the program will modify them to match the thrust profile. If none of the parameters are optimized, the grain will be analyzed one time on the basis of the input parameters.

All of the parameters presented in this menu are shown in *Table A-1* and will be documented later in this Appendix.

A.4.2 Program Control Inputs

Program control inputs are displayed in *Figure A-10*, and the variables are defined in *Table A-2*. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

A.4.3 Basic Propellant Characteristics

Basic propellant characteristics are displayed in *Figure A-11*, and the variables are defined in *Table A-3*. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

A.4.4 Basic Motor Dimensions

Basic motor dimensions are displayed in *Figure A-12*, and the variables are defined in *Table A-4*. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

A.4.5 Basic Performance Constants

Basic performance constants are displayed in *Figure A-13*, and the variables are defined in *Table A-5*. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, pressing in the value, and pressing the Return Key.

A.4.6 Basic Configuration and Arrangement

Basic configuration and arrangement inputs are displayed in *Figure A-14*, and the variables are defined in *Table A-6*. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

Table A-1. Optimization Parameters

Parameter	Description
Initial Throat Diameter	Discussed in Basic Motor Dimensions, shown as DTI in Figure A-22
Nozzle Exit Diameter	Discussed in Basic Motor Dimensions, shown as DE in Figure A-22
Nozzle Exit Half Angle	Discussed in Basic Motor Dimensions, shown as ALFAN in Figure A-22
CP Grain Length with Additional Taper	Discussed in Basic Motor Dimensions, shown as LTAP in Figure A-22
Difference in Web Thickness Associated with LTAP	Discussed in Basic Motor Dimensions, shown as XT in Figure A-22
Difference in Web Thickness Associated with Main CP Length	Discussed in Basic Motor Dimensions, shown as ZO in Figure A-22
Average Internal CP Diameter	Discussed in Basic Motor Dimensions, shown as DI in Figure A-22
Burning Rate Coefficient	Discussed in Basic Propellant Characteristics below transition pressure
Angle Nozzle End of CP Grain to Motor Axis	Discussed in Basic Geometry for CP Grain, shown as THETAG in Figure A-22
Initial Total Length of CP Grain	Discussed in Basic Geometry for CP Grain, shown as LGCI in Figure A-22
Initial Slant Length of CP Grain at Nozzle End	Discussed in Basic Geometry for CP Grain, shown as LGNI in Figure A-22
Initial Total Length of Star Grain	Discussed in Basic Geometry for Star Grain, shown as LGSi in Figure A-22
Fillet Radius of Star Grain	Discussed in Basic Geometry for Star Grain, shown as f in Figures A-23, A-24, and A-25
Web Thickness of Truncated Star	Discussed in Basic Geometry for Standard Star, shown as t in Figure A-23
Web Thickness of Standard Star	Discussed in Geometry for Truncated Star, shown as t in Figure A-24
Web Thickness of Wagon Wheel	Discussed in Geometry for Wagon Wheel, shown as t in Figure A-25
Cusp Radius of Standard Star	Discussed in Geometry for Standard Star, shown as RPNT in Figure A-23

Table A-2. Program Control Inputs

Parameter	Description	Units
Maximum Nozzle Exit Diameter	The maximum allowable nozzle exit diameter. The program internally constrains this value to be twice as great as the initial throat diameter.	in.
Optimization Procedure	Optimization options: 1 - Maximize total impulse to motor weight, 2 - Minimize motor weight, and 3 - Match input thrust versus time history	---
Minimum Nozzle Exit Half Angle	Minimum allowable limit of the nozzle exit half angle. A lower limit of 10° is recommended for a straight conical nozzle. If a bell-shaped nozzle is simulated, the value should be somewhat lower.	deg
Maximum Nozzle Exit Half Angle	Maximum allowable limit of the nozzle exit half angle. An upper limit of 20° is recommended for a straight conical nozzle.	deg
Minimum Throat-to-Port Area	The minimum allowable limit on the throat-to-port area ratio. This value controls the range of the throat diameter. The minimum limit should be selected with a viewpoint toward attaining reasonable volumetric efficiency.	---
Maximum Throat-to-Port Area	The maximum allowable limit on the throat-to-port area ratio. This value controls the range of the throat diameter. Consideration should be given to the erosive burning characteristics of the propellant when specifying this value.	---
Minimum Burning Rate Coefficient	The minimum allowable burning coefficient. Corresponding densities, processing characteristics, and strengths should be considered in selecting this limit.	in./s-psia ⁿ rate
Maximum Burning Rate Coefficient	The maximum allowable burning rate coefficient. Corresponding densities, processing characteristics, and strengths should be considered in selecting this limit.	in./s-psia ⁿ
Minimum fillet Radius	The minimum allowable limit on the star grain fillet radius. Stress considerations would ordinarily govern selection of this value.	in.
Maximum Fillet Radius	The maximum allowable limit on the star grain fillet radius. This value should be selected considering a reasonable volumetric loading density.	in.
Minimum Web Fraction	The minimum allowable web fraction (1.-DI/DO) for a CP grain or grain segment. Since DO is fixed, the value of web fraction is controlled by the average initial internal grain diameter for each configuration. This value should be selected considering volumetric density.	---

Table A-2. Program Control Inputs (Continued)

Parameter	Description	Units
Maximum Web Fraction	The maximum allowable web fraction ($1-DI/DO$) for a CP grain or grain segment. Since DO is fixed, the value of web fraction is controlled by the average initial internal grain diameter for each configuration. This value should be selected with respect to the estimated value of initial throat diameter to avoid excessive erosive burning problems.	---
Minimum Star Grain Web Thickness	The minimum allowable star grain web thickness. The limit will usually be based on the desired total burning time with regard to the value or range of burning rates specified. The user should remember that computer operating time, in general, can be greatly reduced by specifying reasonable ranges of values, especially when the accuracy of the starting value is in question.	in.
Maximum Star Grain Web Thickness	The maximum allowable star grain web thickness. The value might be determined based on desired burning time with some consideration of the general trace shape characteristics obtained with thick-webbed star grains.	in.
Minimum Required Ideal Velocity	The minimum required ideal vehicle velocity. This variable is used only with optimization options 1 or 2.	ft/s
Initial Step Size for Search	The initial step size for the pattern search. A value of 1.0 corresponds to a 5% change in optimization variables for both exploratory and pattern moves.	---
Minimum Step Size	The minimum allowable step size for pattern search. The step size is halved whenever a series of moves fails to produce improvement in the objective function. The search is terminated when the step size becomes less than this value.	---
Maximum Number of Pattern Moves	The maximum number of pattern moves allowed before the search is terminated. This provides the user an additional control over the extent of the search.	---
Search Detail Printout	Controls the amount of data on the details of the search that appears in the program printout 1 - Printout of values of each variable used at each step of the search, the value of the objective function with each move, and identification of basepoints and types of moves (exploratory or pattern) 0 - Minimum printout. Only the values corresponding to basepoints and pattern moves are printed. The final values of the variables are also printed. -1 - Printout consisting only of the final results. This consists of final variable values and the objective function.	---

Table A-2. Program Control Inputs (Concluded)

Parameter	Description	Units
Ballistic Data Printout	Controls the printout of ballistic data. The printouts, when obtained, generally follow the format of the simplified design analysis. Will be printed in file "DOP.OUT". 0 - No output of configurations 1 - Printout initial configuration only 2 - Printout final configuration only 3 - Printout both configurations	---
Flag for Thrust Input Printout	Logical flag for printout of input thrust-time profile if using optimization option 3. The input thrust profile will be printed to a data file named "THRUST.INP".	---
Flag for Thrust Output Printout	Logical flag for printout of output thrust-time profile for optimized motor. The output thrust profile will be printed to a data file named "THRUST.OUT".	---
Flag for Detailed Mass Properties	Logical flag for printout of detailed mass properties information. The data will be printed to file "SOLCG.DAT," which includes data on the CP, star, and tabular mass properties as a function of time. This flag is not necessary for use with the MASTRE Program since it is primarily for analysis purposes.	---
Flag for BARF Effects	Logical flag for the inclusion of BARF effects. If the BARF flag is enabled, two types of input may be in the input data file "BARF.DAT". Figure A-26 shows the two types of BARF input. The variables in the first line of both the tabular and equation input option are the web thickness of the grain for which the data was developed, the web thickness of the grain under consideration, and the input type. For the tabular input option, the tabular values are listed under the first line in distance burned versus burn rate anomaly pairs. These values should continue to the web thickness of the original grain. For the equation input option, two fifth-order equations may be used to specify the burn rate anomaly. The second line contains the effective web thickness of the first equation. The next two lines contain the coefficients of the first and second equations. If lower-order equations are desired, zeros should be entered for the higher-order coefficients.	---

Table A-3. Propellant Characteristics

Parameter	Description	Units
Ratio of Burning Rate Exponents	Ratio of burning rate exponent above and below the transition pressure	---
Propellant Density	Density of the solid propellant	lbm/in. ³
Burning Rate Coefficient	Propellant burning rate coefficient in the equation $r = aP^n$	in./s-psi ⁿ
Burning Rate Exponent	Burning rate exponent in the equation $r = aP^n$	---
First Constant for Erosive Burning	Erosive burning coefficient in the Robillard-Lenoir Burning rate rule	in. ^{2.8} -ft ^{0.8} /s ^{1.8} lbf. ⁸
Second Constant for Erosive Burning	Erosive burning pressure coefficient in the Robillard-Lenoir rule	---
Gas Viscosity	Absolute viscosity of the chamber gases	lbf-s/in.-ft
Characteristic Velocity	Characteristic exhaust velocity. This is the gas dynamic characteristic velocity which can be obtained from the expression $C^* = (R T_c) .5 / G$, where R is the gas constant and T_c is the adiabatic flame temperature of the propellant.	ft/s

Table A-4. Primary Basic Motor Dimensions

Parameter	Description	Units
Total grain length [L]	Total initial perforated grain length including gaps at slots. This is used only for calculation of the initial length Reynolds number and in the erosive burning rate equation.	in.
Average web thickness [TAU]	Web thickness of the controlling propellant length. If the grain is tapered, the length average value should be specified excluding lengths having additional taper not represented by the controlling grain web thickness and segments located anywhere having a step decrease in thickness. Such step decreases must be handled by the additive tabular input option if they introduce two significantly different web thicknesses for the same grain type; e.g., two circular perforated grains. If a circular perforated grain is used, it is assumed that it will have the approximate average web thickness of the controlling propellant length.	in.
Nozzle exit diameter [DE]	Diameter of the nozzle exit	in.
Initial throat diameter [DTI]	Initial diameter of the nozzle throat	in.

Table A-4. Primary Basic Motor Dimensions (Concluded)

Parameter	Description	Units
Nozzle Can't Angle [THETA]	Can't angle of the nozzle with respect to the motor axis	deg
Nozzle Exit Half Angle [ALFAN]	Exit half angle of the nozzle	deg
Length First Tailoff [LTAP]	Estimated axial length of grain at the aft end at the start of first tailoff having an additional taper not represented by either the controlling grain web thickness [ZO] or the nozzle end grain angle [THETAG]. This variable permits the designer to specify an additional taper at the nozzle end of a circular perforated or star grain to produce regressively shortly before tailoff.	in.
LTAP Web Thickness [XT]	Difference in web thickness at ends of LTAP	in.
Controlling Grain Web Thickness [ZO]	Initial difference between web thickness at the head and aft ends of controlling grain length, not including any initial length associated with LTAP or THETAG. The controlling length of the grain is the axial length between the head end of the grain and the position of expected maximum Mach number in the port. It may be assumed, in most cases, that this length terminates whenever there is an abrupt decrease in web thickness near the aft end of the chamber or when THETAG is greater than 5°.	in.
CSTAR Sensitivity	Temperature sensitivity of CSTAR at constant pressure	---
Transition Pressure	Transition pressure for switching N1 to N2 and A1 to A2	lb/in. ²
Axial Reference	Axial distance to top centerline point of grain from solid-motor reference location	in.
Lateral Reference	Lateral distance to top centerline point of grain from solid-motor reference location	in.
Normal reference	Normal distance to top centerline point of grain from solid-motor reference location	in.

Table A-5. Basic Performance Constants

Parameter	Description	Units
Initial Burn Increment [DELTAY]	Initial desired burn increment. This increment will be used by the program for the initial 5% of the web thickness burned, for the period shortly preceding and following tailoff, and at such other times as the rate of pressure change is large. Larger increments will automatically be used at other times. An initial increment size of approximately $0.005 t_w$ is recommended, but larger increments may be used for relatively flat burning surface versus distance burned traces.	in.
Breakup Burn Distance [XOUT]	Distance burned at which the propellant breaks up. This permits the option of specifying termination of burning resulting from possible structural breakup of the propellant. If this option is not desired, the parameter should be set to some large value; e.g., 1,000 in.	in.
Extinguishing Pressure Change [DPOUT]	Rate of change of pressure with respect to distance burned at which the propellant is extinguished. This permits the option of specifying termination of burning resulting from rapid depressurization. If this option is not desired, the parameter should be set to some large value; e.g., 10,000 psia/in. However, if an abrupt tailoff is expected, a smaller value of the parameter must be specified as the computer will not otherwise be able to handle the discontinuity. For a large motors (120 in. diameter and up), a value of 500 psia/in. is recommended and proportionately larger values for smaller motors.	lb/in. ³
Thrust Loss Coefficient	Thrust loss coefficient. In the absence of data to the contrary, a value of 0.98 is recommended.	---
Burn Time	Estimated burning time. This and the estimated burnout altitude permit the program to calculate delivered specific impulse and thrust based on an assumed trajectory determined from analysis of typical large SRM applications.	s
Height of Burnout	Estimated burnout altitude. To obtain sea level performance characteristics, this parameter should be set equal to zero.	ft
Ratio of Specific Heats	Ratio of specific heats for propellant gases	---
Reference Erosion Rate	The reference erosion rate of the nozzle at a stagnation pressure of reference pressure	in./s
Temperature of Grain	The average temperature of the SRM grain at the moment of ignition	°F
Reference Pressure	The nozzle stagnation pressure at which the erosion rate is referenced	lbf/in. ²
Reference Throat Diameter	The reference throat diameter.	in.
Temperature Sensitivity of Pressure	Temperature sensitivity coefficient of at constant K	---

Table A-5. Basic Performance Constants (Concluded)

Parameter	Description	Units
Reference Temperature	The design temperature of the grain. Usually the temperature at which the booster propellant is cured and at which all theoretical ignition simulations are started.	°F
Ratio of Specific Heats at Exit	The effective value of the ratio of specific heats (g) at the exit plane	
Extinguishing Pressure	The pressure at which the propellant extinguishes. Usually near zero.	lbf/in. ²
Initial Atmospheric Pressure	The ambient atmospheric pressure just prior to ignition	lbf/in. ²

Table A-6. Basic Configuration and Arrangement

Parameter	Description	Units
Number of Termination Ports	Number of thrust termination passage-ways in grain. Zero if there are no thrust termination passageways.	---
Diameter of Termination Ports	Figure A-27	in.
Input Type	Input options 1 - tabular input 2 - equation input 3 - combination of 1 and 2	---
Grain Type	Grain type options 1 - entirely circular perforated grain 2 - star grain only 3 - combination of 1 and 2	---
Star Type	Star grain options 1 - standard star 2 - truncated star 3 - wagon wheel (a standard star may not be combined with a truncated star)	---
Star and CP Configuration	Grain order options 1 - a star grain is at the head end and a circular perforated grain is at the aft controlling end 2 - a circular perforated grain is at both ends, a star grain segment may still be present. 3 - a circular perforated grain is at the head end and a star is at the aft controlling end 4 - a star grain is at both ends. If grain type is equal to 1, order must be 2. If grain type is equal to 2, order must be 4. It is important to realize that the grain order establishes the controlling port area equations to be used. Thus, if the nozzle end segment is not indeed the controlling one (the one that establishes the maximum Mach number in the port), the order should be specified to designate the actual controlling segment as the nozzle end segment. The grain type, star type, and grain order are not used for input type equal to one.	---

Table A-6. Basic Configuration and Arrangement (Concluded)

Parameter	Description	Units
Circular Perforated End Configuration	Options for extreme ends of circular perforated grain only: 1 - both ends are conical or flat 2 - head end is conical or flat and aft end is spherical 3 - both ends are spherical 4 - head end is spherical and aft end is conical or flat	---
Number of Tabular Inputs	The number of tabular input sets versus distance burned to be input	---

A.4.7 Tabular Values

Tabular value inputs are displayed in **Figure A-15**, and the variables are defined in **Table A-7**. The variables can be modified by using the up and down Cursor Arrow Keys to high-light the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

A.4.8 Basic Geometry for CP Grain

Inputs for the basic geometry for the circular perforated grain are displayed in the menu shown in **Figure A-16**. The variables of this menu are defined in **Table A-8**. This input is not required for completely star grain or for tabular inputs.

The CP geometry arrays menu allows the user to enter more slot and termination port data for the circular perforated grain. The first two entries are the longitudinal locations of the slots and termination ports. These locations are referenced to the top of the total grain. Next, the number of termination ports may be entered. The termination ports are assumed to be spaced at equal angles perpendicular to the longitudinal axis. Finally, the slot burn directions may be specified. These entries were incorporated to allow the grain in the RSRM to burn longitudinally forward from the field joints, but not backwards. Entering "T" in the fourth row allows the slot to burn longitudinally forward, and entering "T" in the fifth row allows the slot to burn longitudinally backward. If "T" is entered in both rows, the slot will burn both forwards and backwards.

A.4.9 Basic Geometry for Star Grain

Input for the basic geometry for the star grain is display shown in **Figure A-17**. Variables in this figure are defined in **Table A-9**. This input is not required for entirely circular perforated grains or for only tabular inputs. The wagon wheel is considered a type of star grain for the purpose of this program.

The star geometry arrays menu is used in conjunction with the basic star geometry screen. The first two rows of this star geometry screen are used to input the longitudinal locations of the slots

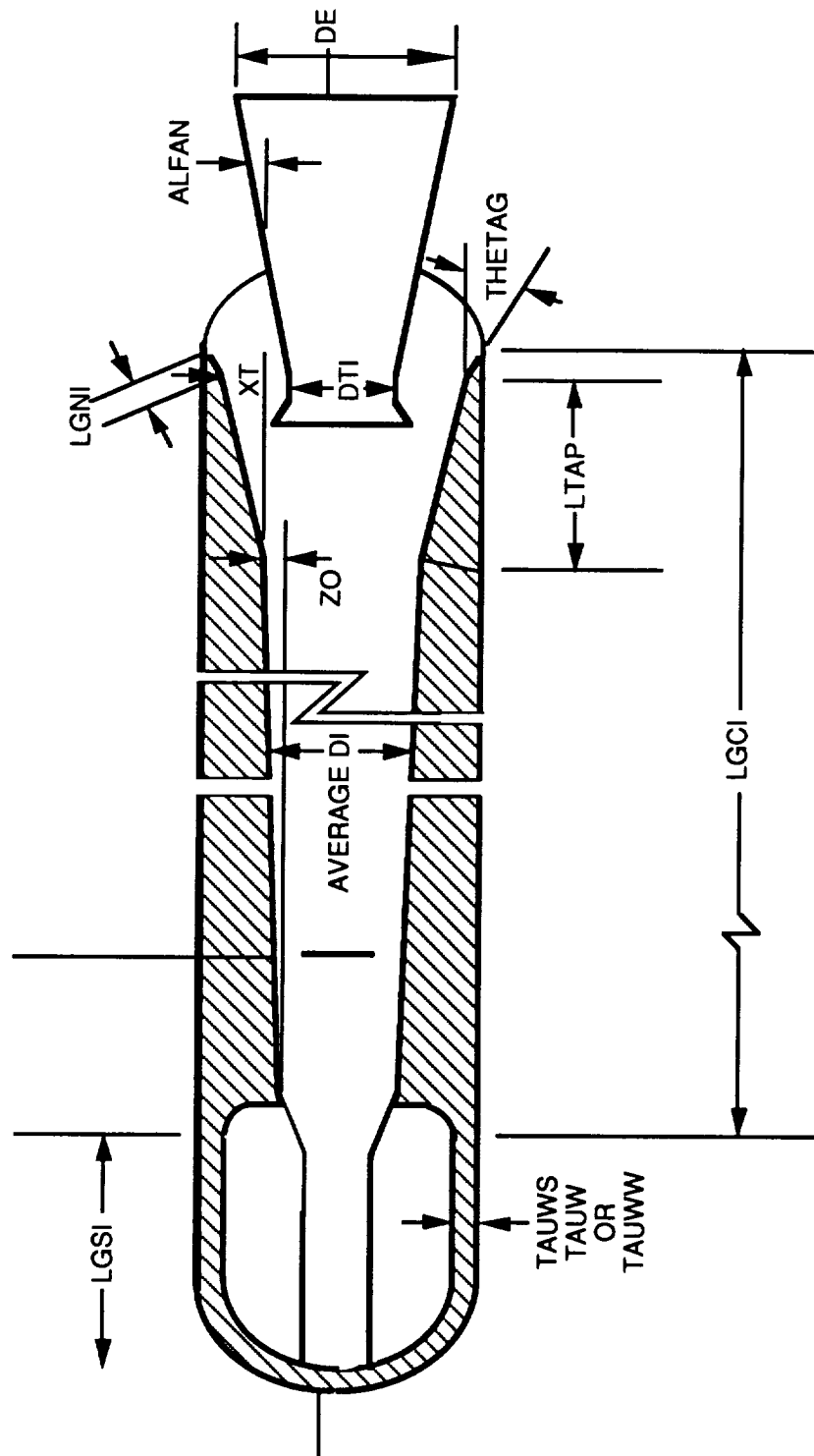


Figure A-22. Basic Motor Dimensions

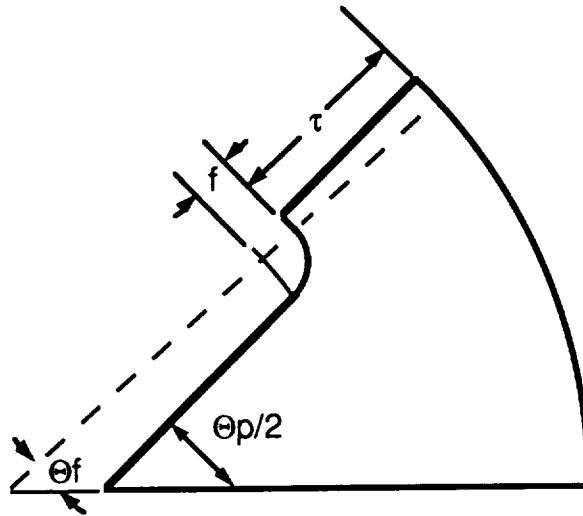


Figure A-23. Standard Star Grain Cross Section

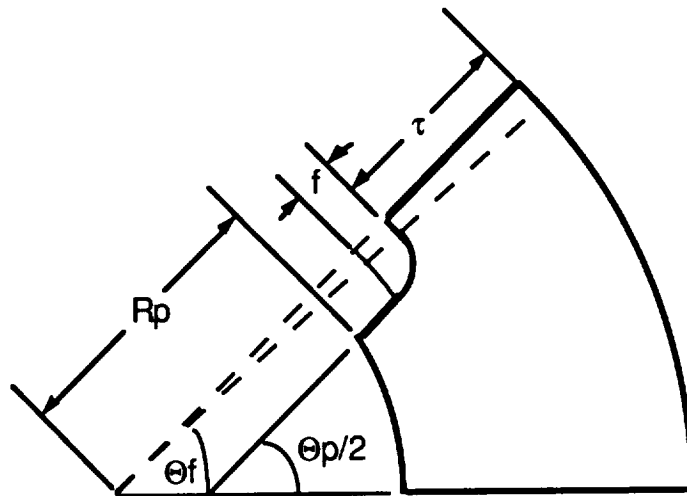


Figure A-24. Truncated Star Grain Cross Section

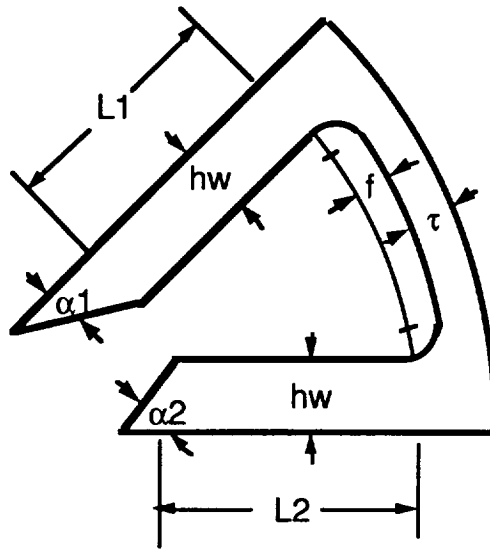


Figure A-25. Wagon Wheel Grain Cross Section

Tabular Input Option	Equation Input Option
43.52 44.65 1	43.52 44.65 2
0.0 0.95	20.0
1.0 0.98	1.1 2.0 3.4 5.3 2.4 1.2
2.0 0.99	4.3 1.0 9.3 0.2 2.6 0.9
3.0 1.01	
4.0 1.02	
5.0 0.97	

Figure A-26. BARF Input Options

and termination ports for the star grain segment. These locations are referenced to the top of the total grain. The third row is used to enter the number of termination ports at each location. The termination ports will be equally spaced in a circle perpendicular to the longitudinal axis. The last two rows allow the user to specify the burn directions of the slots. The slots may burn longitudinally forward if "T" is specified in the fourth row, or longitudinally backward if "T" is specified in the last row. If "T" is specified in both rows, the slot will burn both ways. This option was incorporated because the RSRM grain was observed to burn forward from the field joints but not backward.

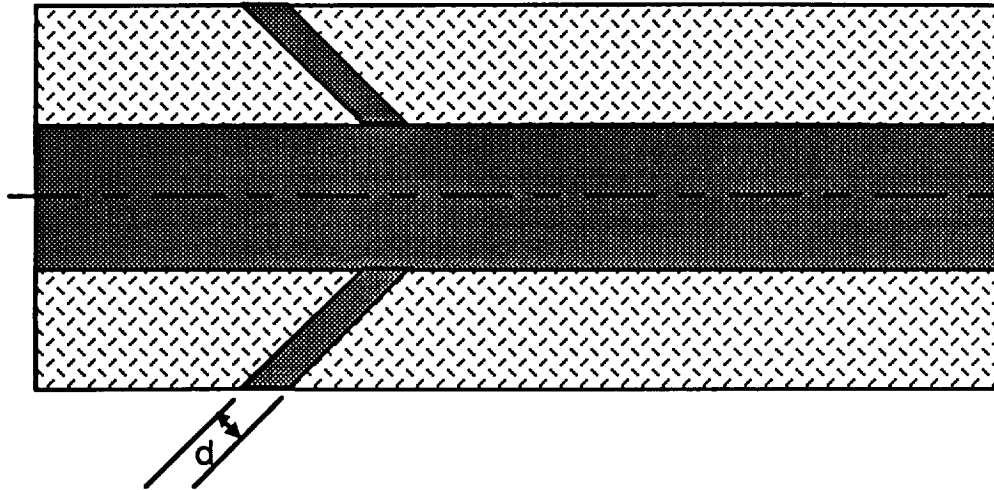


Figure A-27. Termination Port for Solid Motor

A.4.10 Geometry for Standard Star

Input for the standard star geometry is displayed in **Figure A-18**. Variables in the figure are defined in **Table A-10**. This input is not required for truncated star grains.

A.4.11 Thrust Versus Time Data

The thrust versus time data screen shown in **Figure A-19** allows the user to input a thrust versus time history that the solid module will try to match by optimizing the chosen parameters in the Optimization Parameter screen. The variable in the figure are defined in **Table A-11**. Up to 20 thrust versus time points may be entered in the array screen. Only used if optimization option 3 is selected in Program Control Inputs menu.

Table A-7. Tabular Values

Parameter	Description	Units
Distance Burned	Distance burned independent table	in.
Port Area	Burning area in the port	in. ²
Slot Area	Burning area in the slots	in. ²
Nozzle Area	Burning area at the nozzle end	in. ²
Port Area at Head End	Port area at the head end of the grain. Port areas are not required when the input type is either 2 or 3; the equation inputs must be used to provide the information in these cases. Values of all areas used must be specified to completely describe the burning surface and port areas versus distance burned. The program computes intermediate values by linear interpolation. The number of values required is arbitrary and limited only by the storage capacity of the computer. The use of these tabular values in conjunction with the equation inputs (input type = 3) increases the flexibility of the program considerably.	in. ²
Initial Volume of Chamber Gases	Initial volume of chamber gases associated with tabular input	in. ³
Mass Left	Mass of the tabular inputs left at the current distance burned	lbm
CG of Mass Left	Axial CG of tabular inputs at current distance burned, referenced to solid motor reference location	in.

Table A-8. Basic Geometry for CP Grain

Parameter	Description	Units
Average Outside Diameter [DO]	Length average outside diameter of circular perforated grain, excluding lengths extending into the closure	in.
Average Inside Diameter [DI]	Length average inside initial diameter of circular perforated grain. Only the controlling length excluding the length of first tailoff [LTAP] should be considered in the averaging.	in.
Number of Flat Ends	Number of burning flat ends of a circular perforated grain not including an extreme aft grain end	---
Angle of Grain at Nozzle End [THETAG]	Angle between the burning surface element of circular perforated grain located at the extreme nozzle end of chamber and the motor axis. Must be set to zero if a star grain is located at the nozzle end (grain type = 3, order = 3) or if aft end burning surfaces are represented by tabular values. Must be 90° if the circular perforated grain represented by equations has a flat burning surface located at the extreme nozzle end of the chamber. If less than or equal to 5°, a value must be assigned (zero is satisfactory), but the effect of the angle on burning surface area is not computed. The angle is zero if the end surface is flat and inhibited.	deg

Table A-8. Basic Geometry for CP Grain (Concluded)

Parameter	Description	Units
Total Grain Length [LGCI]	Initial total axial length of circular perforated grain represented by equation inputs not including gaps. Lengths associated with THETAG are excluded.	in.
Slant Length Associated with THETAG [LGNI]	Initial slant length of a burning conical circular perforated grain at the nozzle end. Is set equal to zero if THETAG is less than or equal to 5°. In this case, the length otherwise associated with the slant length should be added to the total grain length. If the error in burning surface area thus introduced is deemed significant, a correction may be introduced by making use of tabular inputs in combination with the equation inputs. Basic effect of small THETAG on tailoff may be accounted for by specification of the length of the first tailoff [LTAP]. If a nozzle end burning surface is flat, the parameter equals one-half the difference between inside and outside local grain diameters.	in.
Contraction Angle at Nozzle [THETCN]	The contraction angle of a circular perforated grain bonded to the nozzle closure. This parameter is not required if the circular perforated end configuration option is either 1 or 2. Use an estimated value that yields approximately the correct volume of propellant burned. If a star shaped grain is located at the extreme nozzle end of the chamber or if tabular values are used to represent downstream burning surfaces, the angle is 90°. The angle is also 90° if the extreme aft end of the grain is inhibited, but only a flat-ended inhibited grain that does not extend into the nozzle closure may be accurately represented. The angle is 0° for a burning flat end that does not extend into the closure.	deg
Contraction Angle at Head End [THETCH]	This parameter is not required if the circular perforated end configuration option is either 2 or 3. Use an estimated value that yields approximately the correct volume of propellant burned. The angle is 90° if the extreme forward end of the circular perforated grain (bonded or not) represented by equations is flat. A head end flat burning surface is treated by proper specification of the number of flat ends.	deg
Slot Widths	Beginning widths of slots in circular perforated grain. One value is used for all slots (shown in Figure A-28).	in.

Table A-9. Basic Geometry for Star Grain

Parameter	Description	Units
Number of Flat Ends	Number of burning flat end surfaces of a star grain not located at extreme nozzle end of the chamber	---
Total Length [LGSII]	Initial total axial length of star-shaped perforated grain represented by equations. No provision comparable to the use of LGNI for circular perforated grains is made here to treat effects resulting from THETAG greater than 5°. Adjustments may be made, however, by use of tabular input values in conjunction with the equation input. Also, effects of taper, including additional small taper at the nozzle end, on tailoff may be treated by use of the variables ZO, XT, and LTAP.	in.
Number of Points	The number of star points	---
Outside Radius	The star grain outside radius	in.
Fillet Radius	The fillet radius at star valleys	in.
Number of Flat Nozzle Ends	Number of burning flat end surfaces (0 or 1) of a star grain located at the extreme nozzle end of the chamber	--

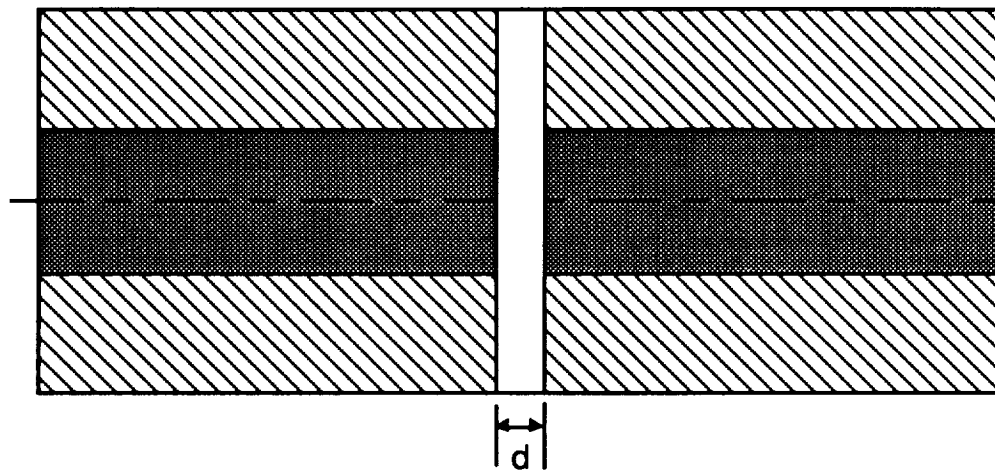


Figure A-28. Slot for Solid Motor

Table A-10. Geometry for Standard Star Grain

Parameter	Description	Units
Angle Location of Fillet [THETAF]	Angular location of the fillet center of standard star from line of symmetry	deg
Apex Angle [THETAP]	The apex angle of the star point	deg
Web Thickness [TAUWS]	The web thickness of a standard star grain. If the grain is tapered, the length average value should be used. This parameter will be the same as TAU if the entire controlling length of grain is a star grain.	in.
Cusp Radius [RPNT]	Star grain cusp radius	in

Table A-11. Thrust Versus Time Data

Parameter	Description	Units
Number of Points	The number of thrust versus time data points to be used for the thrust versus time trace	---
Objective Function Scaling Factor	Scales objective function to a meaningful value of 1e-08 was used for the RSRM	---
Time	The time of the thrust inputs	s
Thrust	The thrust at the current time	lbf
Weighting Factors	The weighting factor for each thrust time pair. If all points are to be weighted equally, 1.0 should be used for the factor.	---

A.4.12 Geometry for Wagon Wheel

Wagon wheel geometry inputs are displayed in **Figure A-20**, and the variables are defined in **Table A-12**. The variables can be modified by using the up and down Cursor Arrow Keys to highlight the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

A.4.13 Geometry for Truncated Star

Truncated star geometry inputs are displayed in **Figure A-21**, and the variables are defined in **Table A-13**. The variables can be modified by using the up and down Cursor Arrow Keys to highlight the selection, pressing the Select Key, keying in the value, and pressing the Return Key.

Table A-12. Geometry for Wagon Wheel

Parameter	Description	Units
Web Thickness	The web thickness of wagon-wheel grain. The discussion for standard star grain web thickness is applicable.	in.
Length of First Side	The length of the first of the parallel sides of the first and second set of grain points	in.
Length of Second Side	The length of the second of the parallel sides of the first and second set of grain points.	in.
Angle of First Point	The angle between the slant side and the centerline of the point of the first grain point. Should not exceed $p/2$.	rad
Angle of Second Point	The angle between the slant side and the centerline of the point of the second grain point. Should not exceed $p/2$.	rad
Star Half Width	The half-width of the star points. Must not exceed web thickness.	in.

Table A-13. Geometry for Truncated Star

Parameter	Description	Units
Radius of Truncation	The length average initial radius of the truncation	in.
Web Thickness	The length average initial thickness of the propellant web at the bottom of the slots	in.

Once all of the input screens that required modification have been edited, the "Return to New CGs" option should be selected from the Menu screen. After this, the user will be given the option to save the data just edited, **Figure A-29**. If the data are saved with the old name, the previous data will be erased, but if a new name is entered that corresponds to one already in the directory, the name will be used except with a higher version number. After saving the data, the user will be presented with choices about file calculation. When these selections have been made, the program will return to the "New CGs" menu.

A.5 THROTTABLE AND NONTHROTTABLE LIQUID ENGINE MODULES

A liquid engine module is composed of all the liquid fuel, fuel tanks, oxidizer, oxidizer tanks, pressurization gas, pressurization tanks, and inert components in a liquid engine. The tanks are allowed to have ellipsoidal, ogival, or flat ends, while the midtank section is assumed to be a cylinder. The tank elements are shown in **Figures A-30 through A-32**. Also, tabular inputs of CG location versus mass overboard are allowed for a specific tank or for the entire module. The tanks are assumed to be pressurized by a pressurization gas, either bled from the engine or from another onboard tank.

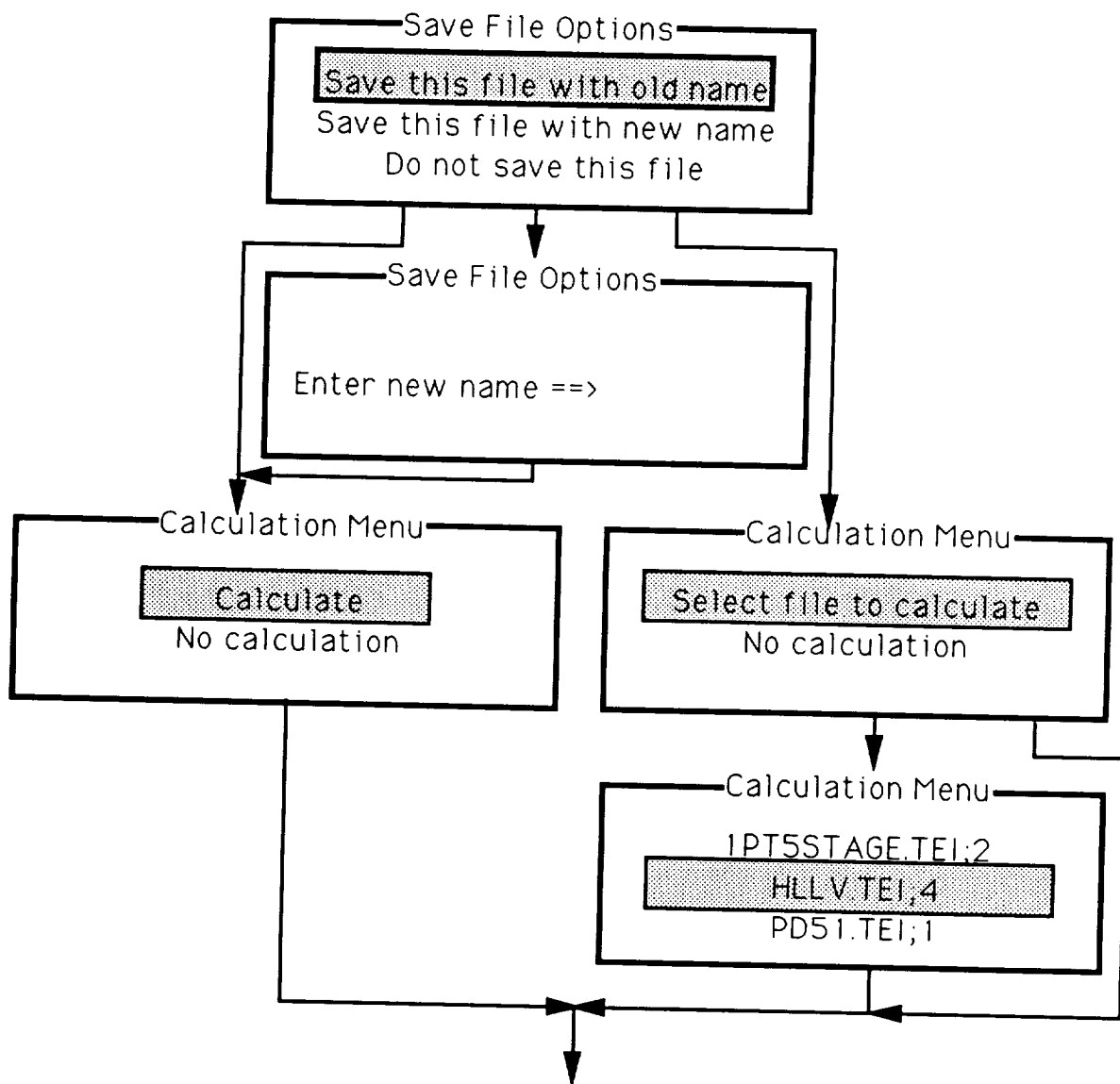


Figure A-29. Final Solid Module Selections

All of the input throttleable files have a ".TEI" extension, and all of the input nonthrottleable files have a ".NEI" extension. The output files, have ".TEM" and ".NEM" extensions, respectively.

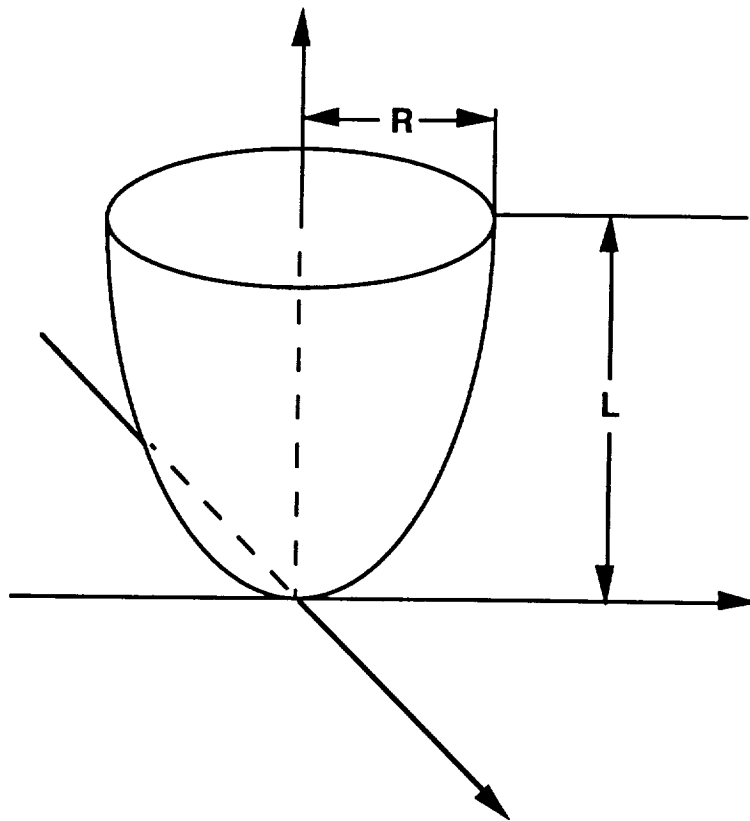


Figure A-30. Revolved Ellipse Endcap

For this module, the CG of the liquid in a tank was assumed to cause longitudinal changes in the CG only. No CG changes in the lateral or normal directions are allowed. The top surface of the liquid was assumed to remain perpendicular to the longitudinal axis of the tank. Also, the liquid was assumed not to slosh, the density of the fuel and pressurization gas was assumed to be constant, and no mixing was assumed to occur between the liquid and pressurization gas. Finally, no vortices were allowed.

The screens and logical flow of the user interface for the throttleable and nonthrottleable liquid engines are shown in **Figure A-33**. The sample data is the data used to develop the 1.5 Stage Common Core. In these data, the ".TEI" extensions may be replaced by ".NEI" extensions for a nonthrottleable engine.

The liquid engine modules are accessed by selecting "Throttleable Engines" or "Nonthrottleable Engines" from the screen in **Figure A-2**. After this, the sequence in **Figure A-33** is followed.

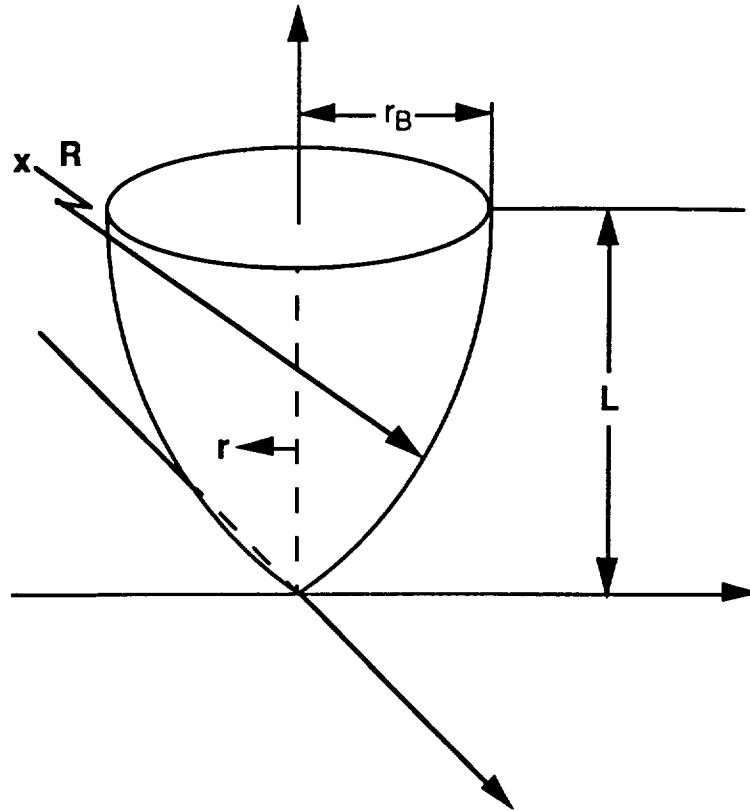


Figure A-31. Revolved Ogive Endcap

The first set of screens allow the user to choose whether to work with old data files or to use new data files. Old data files may be used if data are to be corrected, checked, or used as a basis for creating a new file. Once the file selection has been made, the "Engine Data" screen is displayed.

The "Engine Data" screens allow the user to specify the tank parameters for the liquid engine. There is a complimentary screen that coordinates with this screen and may be accessed by using the Prev Scrn and Next Scrn Keys. To move internally in the screen, the Arrow Keys may be used. Also, tanks may be added and deleted by pressing the Insert and Delete Keys.

The first screen allows the user to specify the type of tanks and the physical dimensions of the tanks. The tank types, second column, are standard, pressurization, and tabular. The standard tank is just a conventional fuel or oxidizer tank. A pressurization tank is one that is used to pressurize a fuel or oxidizer tank without adding any mass to the mass overboard. The tabular tank is for tanks that cannot be described physically by dimensions or for tanks that already have known CG properties. This option can also be used for an entire engine to specify its mass overboard versus CG location.

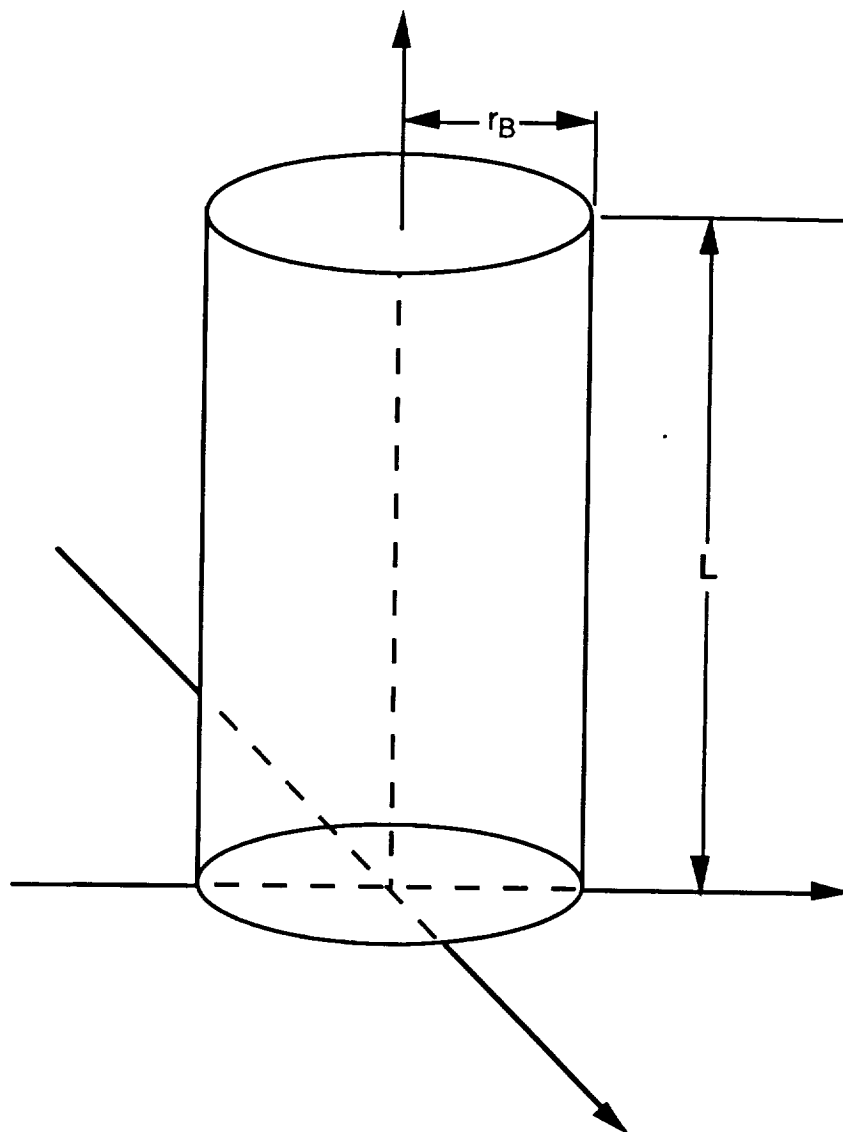


Figure A-32. Cylindrical Midtank

The rest of the entries in the table are physical dimension variables. The height of the tank, column three, is the height of the cylindrical portion of the tank (see **Figure A-32**). If the tank is spherical, this value is zero. The radius of the tank, column four, is the cross sectional radius of the cylindrical portion or the end portion of the tank. Next, the endcaps of the tank may be either ellipsoidal, ogival, or flat. The ends are shown in **Figures A-30 and A-31**. The options of ellipsoidal or ogival are selected in the top and bottom end type columns, columns five and seven. The heights of these ends, columns six and eight, are the longitudinal height of the end. To specify a flat end, a height of zero should be entered.

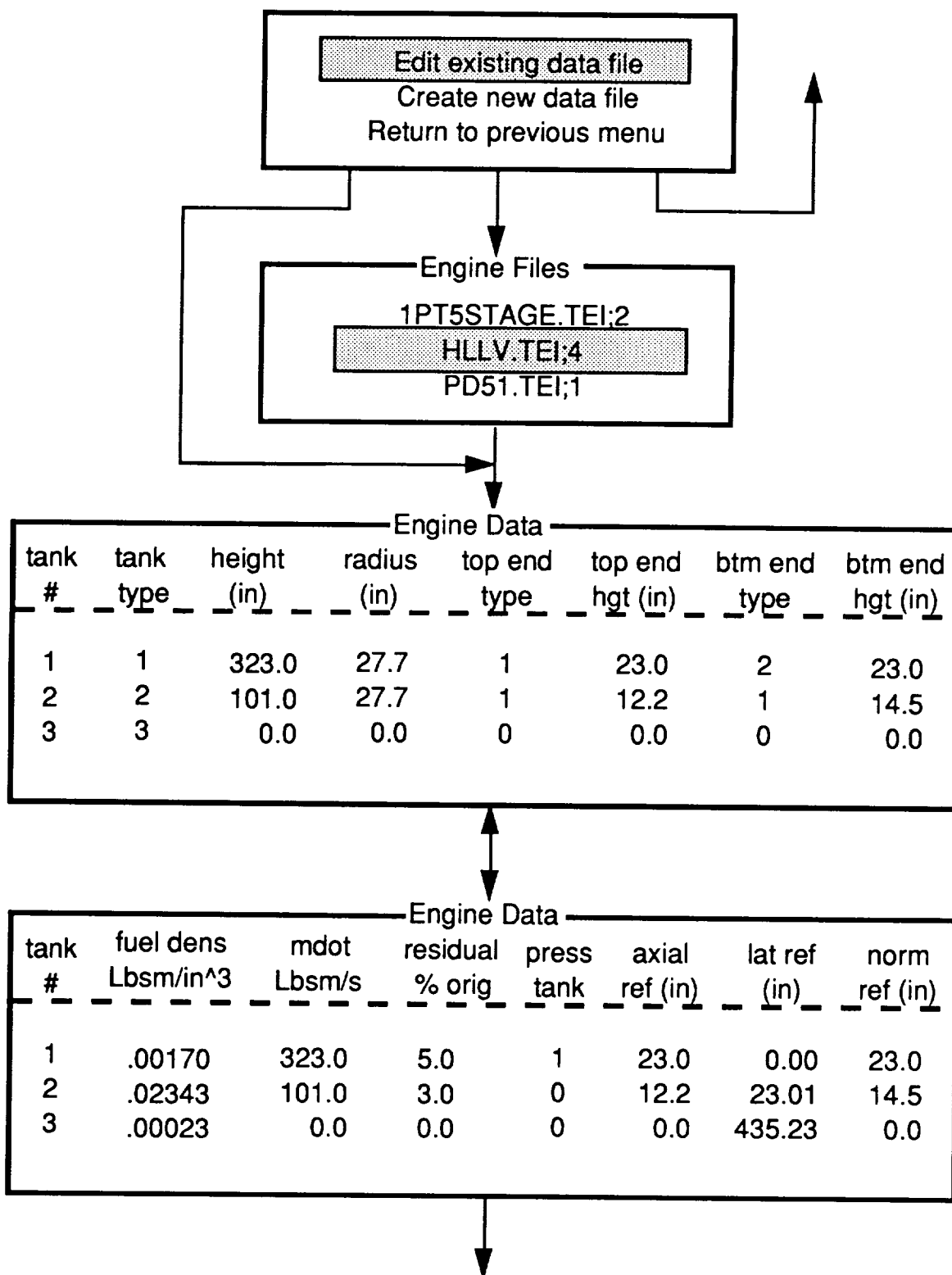


Figure A-33. Throttleable and Nonthrottleable Engine Module Flow Diagram

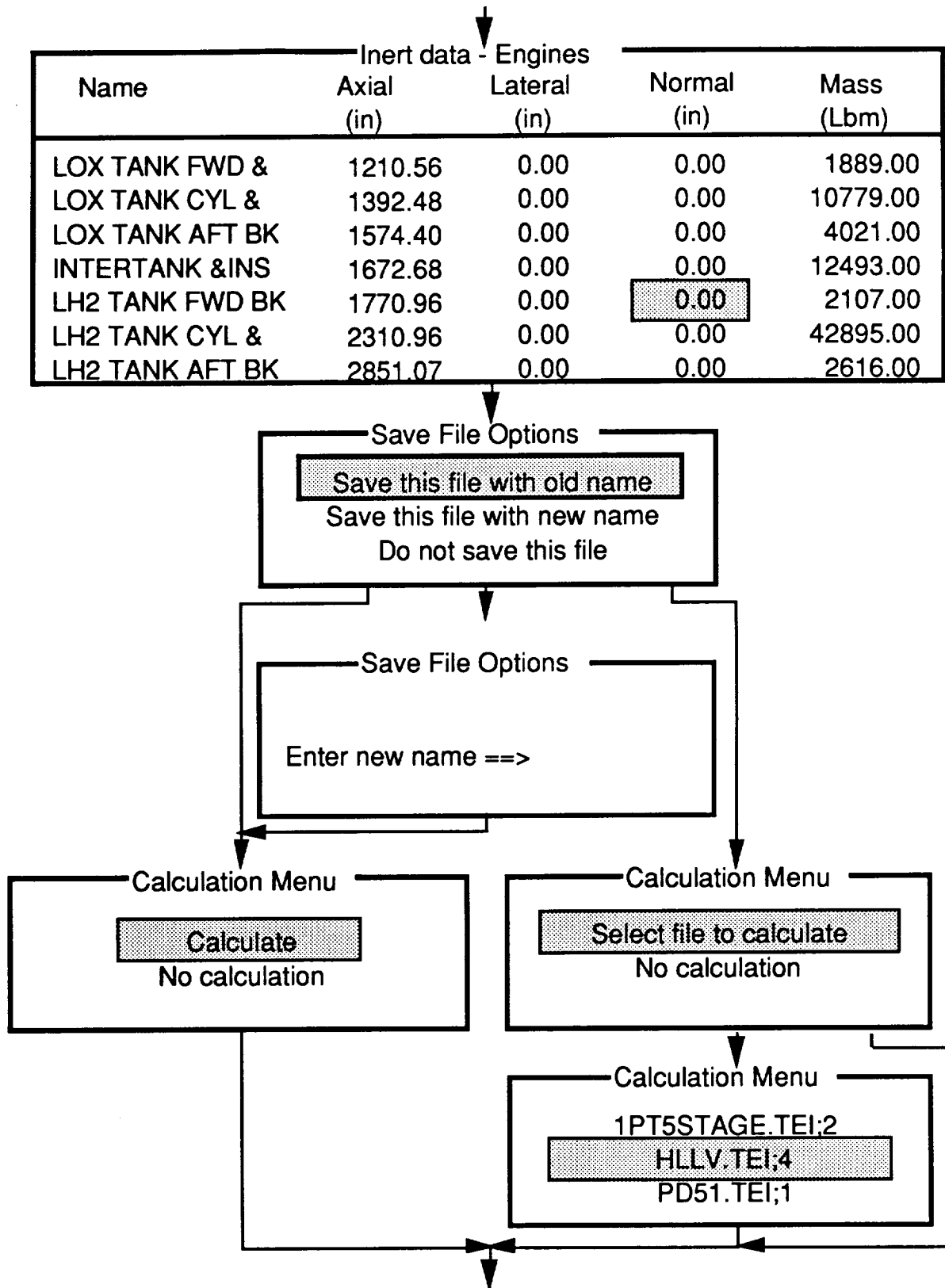


Figure A-33. Throtttable and Nonthrotttable Engine Module Flow Diagram

The corresponding screen of engine data allows the user to enter other tank parameters. **Note, the tank numbers in the first column correspond directly with the tank numbers on the previous screen.** The fuel density, column two, is the density of the fuel in the tank. The mass flowrate, column three, is the average mass flowrate of the tank over the entire use of the tank. Column four are the values expected for the residuals to be left in the tank as a percentage of the initial mass. Pressurization tanks are coordinated with the tanks that they pressurize by entering the associated pressurization tank number in column five. One pressurization tank is not assumed to pressurize only one tank. The final three columns allow the user to enter the reference location of the tank in the local engine reference system. The engine is assumed to be referenced at the bottom center line point of the tank (see **Figure A-34**).

The tabular data option for the liquid tanks is shown in **Figure A-35**. In this screen, tank number three is a tabular tank. When the high-light bar is on the third row, the tabular values appear. These values may be edited by using the Next Scrn Key. Because the tank is entered in tabular form, there are no physical dimensions associated with it. All of the other entries on the row are zero. However, the entries on the second screen must be completed. The reference location for the tank is again the bottom center line location of the tank referenced to the local tank coordinate system.

Once the data that specify the tanks and fuel of the engine are input, the program asks the user for inert property data. The inert property data expected are unique to the liquid engines. By including the unique liquid engine data with the fuel and tank data, transportability to other vehicle configurations is maintained. These expected inputs are the name, mass, and reference location of the inert components. The reference location and the CG locations should be referenced to the local engine coordinate system used for the tanks.

Saving and calculation options are the final choices to make in the liquid engine modules. An edited module may be saved with its old name, a new name, or not saved. If it is saved with its old name, the new data are written over the old data; if it is saved with a new name, no old data are lost. The file does not have to be saved if errors occurred in it. The calculation options are allowed after saving. If the file was saved, it may or may not be calculated. If the file was not saved, another file may be selected for calculation if desired.

After these options, the liquid engine module sequence is complete.

A.6 HYBRID ENGINE MODULE

The Hybrid Engine Module is composed of the liquid tanks, liquid fuel, solid grain, grain casing, and inert components that compose a hybrid engine. A created module is self contained and

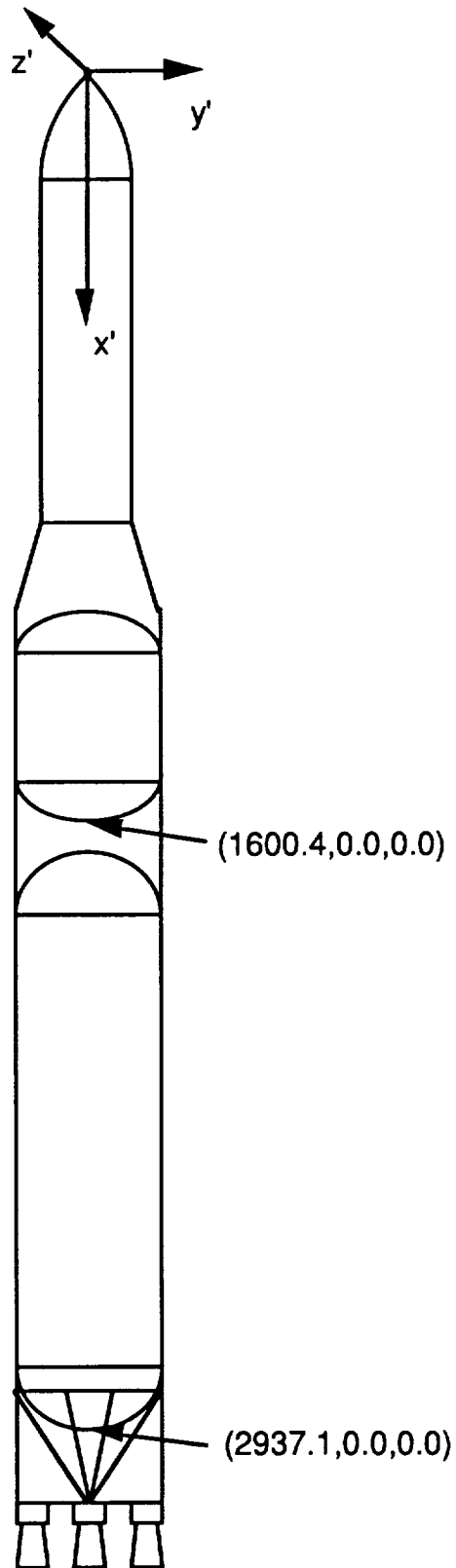


Figure A-34. Liquid Engine Reference Locations

can be easily transported to other vehicle configurations. The expected vehicle configuration is shown in **Figure A-36**.

Engine Data							
Tank #	Tank type	Height (in)	Radius (in)	Top end type	Top end hgt (in)	Btm end type	Btm end hgt (in)
1	1	323.0	27.7	1	23.0	2	23.0
2	2	101.0	27.7	1	12.2	1	14.5
3	3	0.0	0.0	0	0.0	0	0.0

tabular cg's	
0.0	135.4
100.0	120.2
200.0	118.4
300.0	98.4
400.0	45.3
500.0	35.9
600.0	135.3

****Tank Types****
 *1=conventional *
 *2=pressurization *
 *3=tabular *

Figure A-35. Throttleable and Nonthrottleable Liquid Engine

There are two important limitations of this module. First, the module does not include the complex equations required to calculate the burning rate of the grain. Therefore, the user must provide the flowrate and mixture ratios of the liquid and solid propellant versus time. Also, if the grain geometry is not entered in tabular form, it is assumed to be circularly perforated and burn outward at a symmetrical radial rate, which means that the grain CG will be at the middle of the grain length and will not change.

To build a hybrid module, "Hybrid Engines" is selected from the "New CGs" menu. The first choice that the user must make is whether to use new or old data files. All of the input files have a ".HMI" extension, and all of the output files have a ".HMM" extension. An old data file may be used for review or as a starting point to build a new file. If an old file is chosen, the user is given the choice of any of the available files in the directory. Once the choice of file type is made, data insertion begins.

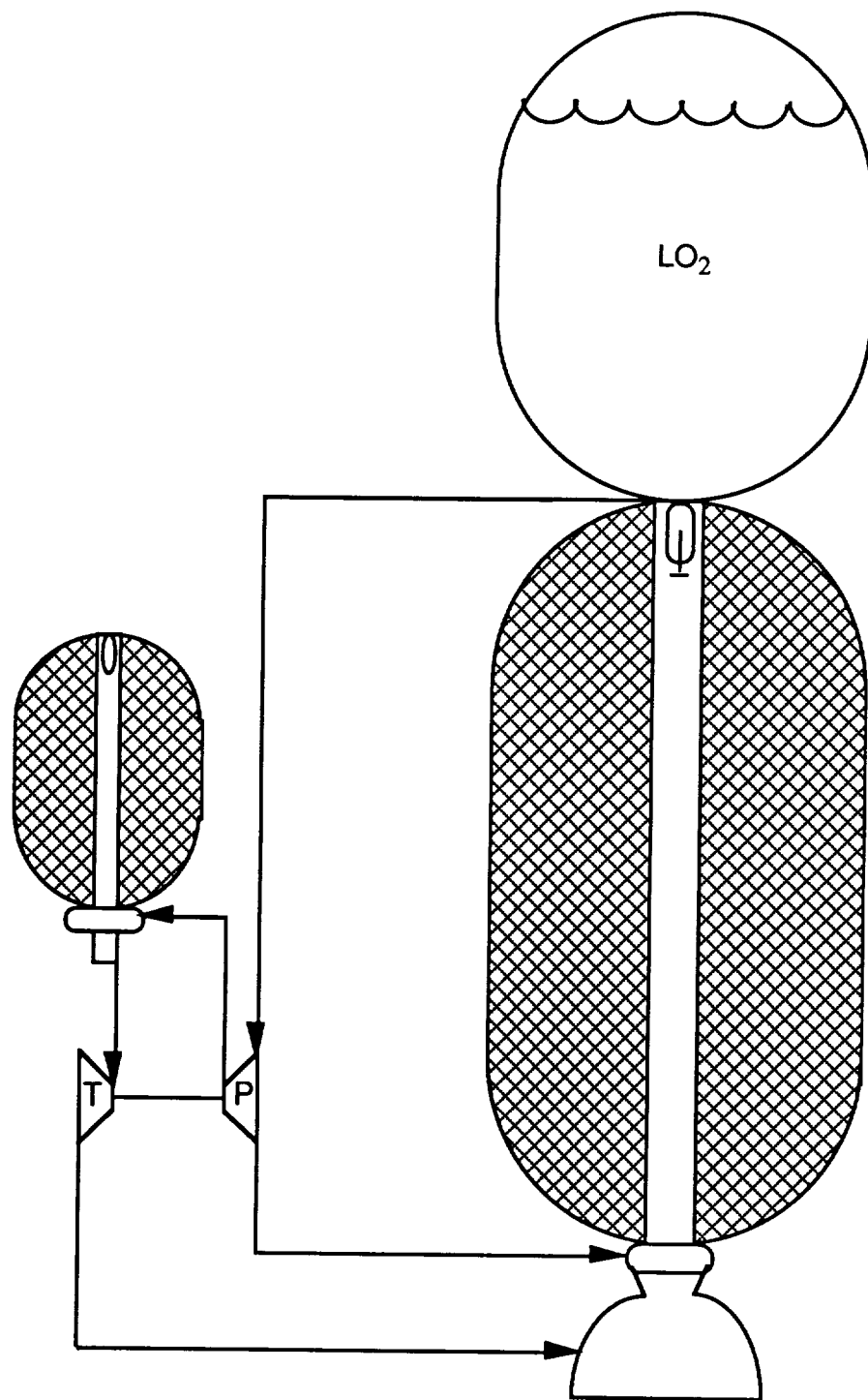


Figure A-36. Hybrid Engine Configuration

The first set of data that the user must enter is the liquid propellant data, in the "Engine Data" screens. Two screens are present here and may be accessed by using the Prev Scrn and Next Scrn Keys. Tanks may be added or deleted by using the Insert and Delete Keys.

The first screen allows the user to specify the physical dimensions of the liquid tanks. In the second column, the user is allowed to enter the tank type. The types are conventional, pressurization, and tabular. The pressurization tank is used to pressurize any other type of tank, but its mass will not be considered as mass that will flow overboard. Column three contains the height of the cylindrical portion of the tank (see **Figure A-37**), and column four is used for the cross sectional radius of the tank. The final inputs for the first screen are for the top and bottom ends. The ends may be ellipsoidal, ogival, or flat. The type signifier for the top and bottom ends is entered in columns five and seven, respectively. The height of the ends is entered in columns six and eight. The height is the longitudinal height of the tanks. If a flat end is specified, its type should be ellipsoidal with a height of zero.

By switching screens, the propellant, tank associations, and reference locations may be entered. The numbers in column one of the second screen correspond directly with the numbers in column one on the first screen. Columns two and three contain the fuel density and average mass flowrate of the fuel for a tank. The average mass flowrate is the expected average of the entire use of the tank. Column four allows the user to enter the expected residual amount to be left in the tank. This amount is a percentage of the original mass. The next entry, column five, associates the pressurization tanks with the tanks that require pressurization. The number of the pressurization tank should be entered in the row of the tank to be pressurized. Finally, the bottom center line position of each tank is referenced to the local engine coordinate system (see **Figure A-38**).

The tabular data option for the liquid tanks is shown in **Figure A-39**. In this screen, tank number three is a tabular tank. When the high-light bar is on the third row, the tabular values appear. These values may be edited by using the Next Scrn Key. Because the tank is entered in tabular form, there are no physical dimensions associated with it. All of the other entries on the row are zero. However, the entries on the second page must be completed. The reference location for the tank is again the bottom center line location of the tank reference to the local tank coordinate system.

Upon completion of the liquid tank data, the grain data and mixture data may be edited. Switching between screen is accomplished using the Next Scrn Key. The grain may be entered in either tabular form or parameter form. If the tabular form is chosen, the program will expect the longitudinal CG location of the grain to be entered as a function of mass overboard in the far right window. This window can hold up to 30 entries. If the parameter form of the hybrid grain is chosen, the length, mass and reference location of the grain are entered in the top left window. The reference

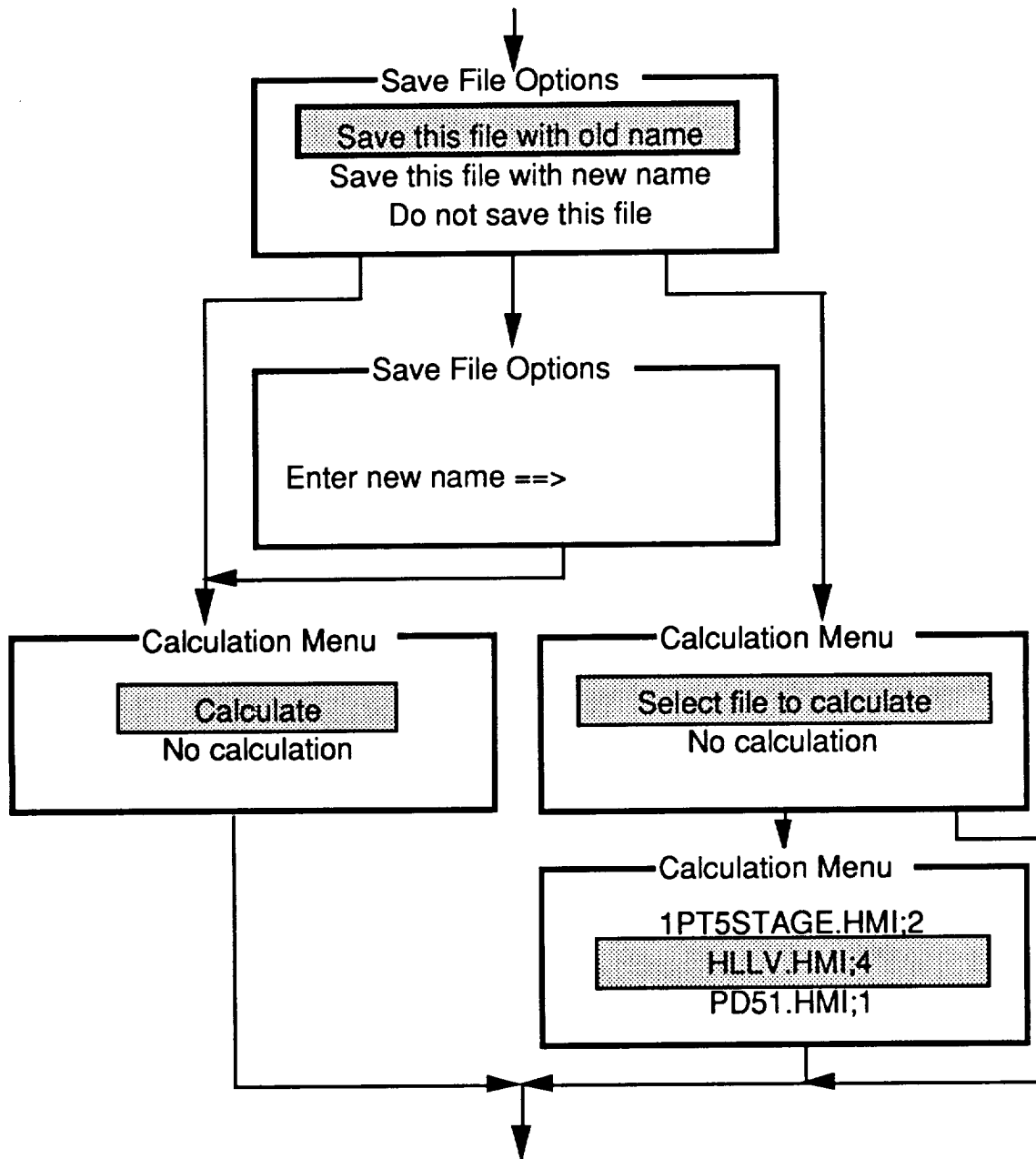


Figure A-37. Hybrid Module Flow Diagram

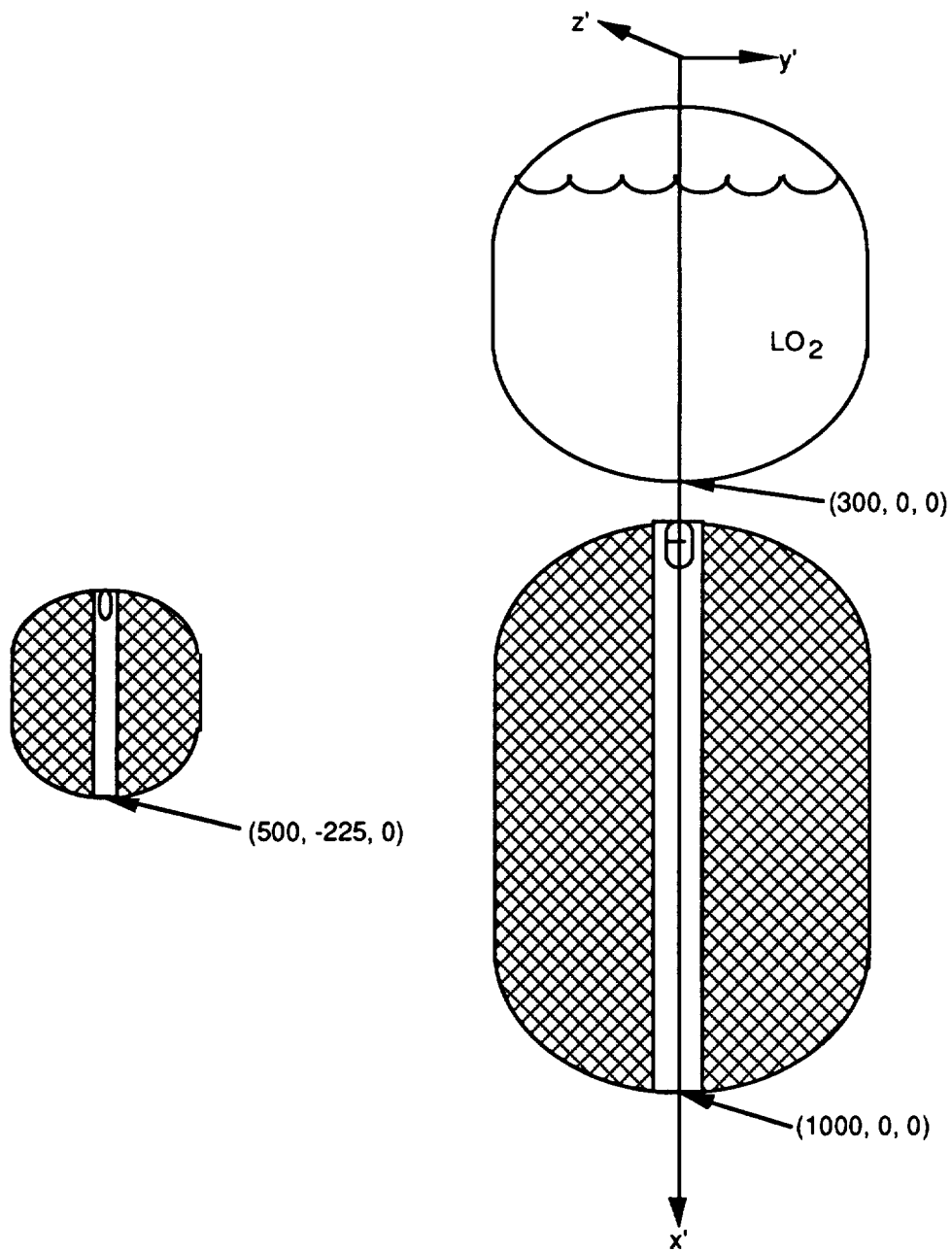


Figure A-38. Example Hybrid Reference Locations

location is from the bottom of the grain to the local coordinate system (see **Figure A-38**). The reference location of the grain still needs to be input in this window if the tabular option is used.

Engine Data							
Tank #	Tank type	Height (in)	Radius (in)	Top end type	Top end hgt (in)	Btm end type	Btm end hgt (in)
1	1	323.0	27.7	1	23.0	2	23.0
2	2	101.0	27.7	1	12.2	1	14.5
3	3	0.0	0.0	0	0.0	0	0.0

****Tank Types****

*1=conventional *

*2=pressurization *

*3=tabular *

tabular cg's

0.0	135.4
100.0	120.2
200.0	118.4
300.0	98.4
400.0	45.3
500.0	35.9
600.0	135.3

Figure A-39. Engine Data Screen With Tabular Inputs

The final entry in this section of screens is the time, flowrate, and mixture ratios. The program does not compute the burning rate of the solid grain and its combination with the liquid. Therefore, the user must input the total flowrate of the liquid and solid together and the mixture ratio of the liquid to solid by mass. This table is very important for the hybrid engine to produce accurate results. Up to 25 values may be entered here.

After the grain and mixture data are entered, the inert components associated with the engine are specified. The expected program inputs are the name, reference location, and mass of all of the inert components. Again, the inert components should be referenced to the same local coordinate system as the liquids and solids previously entered.

The file saving and calculation options are the last things to be determined. The file may be saved with an old name, which will write over the data of the file that was opened, or the file may be saved with a new name. If there is already a file with this name, this file will be created with a higher version number. The other option is used if mistakes have been made and no action is to be taken.

After these choices, the user is given calculation choices for the file just created, or for other files. If the file is not saved, the user is given the choice to calculate another file.

A.7 MERGE MODULE

The formation of the data to be used by MASTRE is performed after all of the individual modules that are needed for a particular vehicle have been created. Each individual module created will be self contained (inerts and fuel together) during its construction, but the modules will be decomposed and recombined to form an overall vehicle configuration.

To begin merging the modules, "Merge Module" is selected in the "NEW CG's" menu. After this, the user is offered the choices of using an old data file or creating a new data file (see **Figure A-40**). Old data files may be used to check for accuracy or to begin building a new data file. If the old file option is chosen, all of the available merge files in the directory will be displayed, and the user may choose from them. All of the old input files have a ".MRG" extension, while all of the old output files have a ".MMM" extension.

After the type of file has been selected, the inert payload module selections are made. All of the available files in the directory will be displayed in the left screen for the user (see **Figure A-40**). If the user has specified an old data file, any inerts selected in that file will be displayed in the right hand screen. By highlighting and pressing the Select Key, the user should select the files in the left screen that will be used for the vehicle, and they will then appear in the right screen. If any modules are mistakenly transferred, or any of the modules are obsolete, the user may go to the right screen and delete any of the entries that are invalid.

Once all of the inert payload files that are needed for a vehicle have been selected and placed in the right window, the user should enter their respective reference locations in the right screen. For the case shown (see **Figure 4-40**), the 1PT5STAGE.IPM module is referenced to the tip of the nose of the 1.5 Stage Common Core vehicle when it was created. However, the global coordinate system is 1306.6 inches in front of the local system. Therefore, a reference length of 1306.6 is entered. No lateral or normal reference lengths are entered for this case because the two coordinate systems differ only in their axial location. Up to 10 inert payload modules may be entered in the inert payloads section for merging.

After the inert payloads files have been selected and referenced, the boosters will be selected. The first screen that the user will encounter is the "Select Booster Type" screen. The user is presented this screen so that the booster type may be selected. This selection prevents the user from using different type of boosters, hybrid and solid for example, on the same vehicle and will prevent all of the engines and motors in the directory from being displayed.

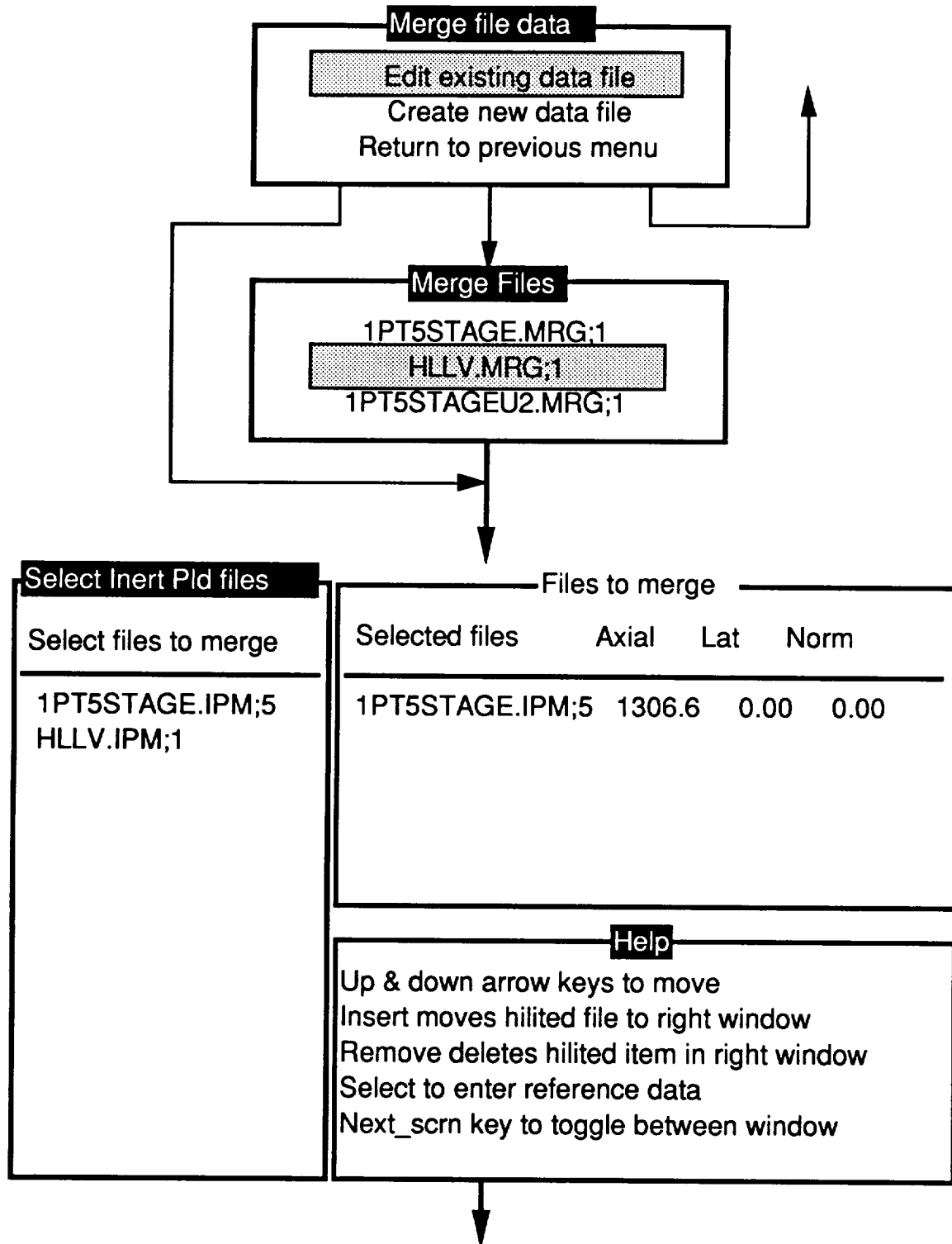


Figure A-40. Merge Module Input Menus

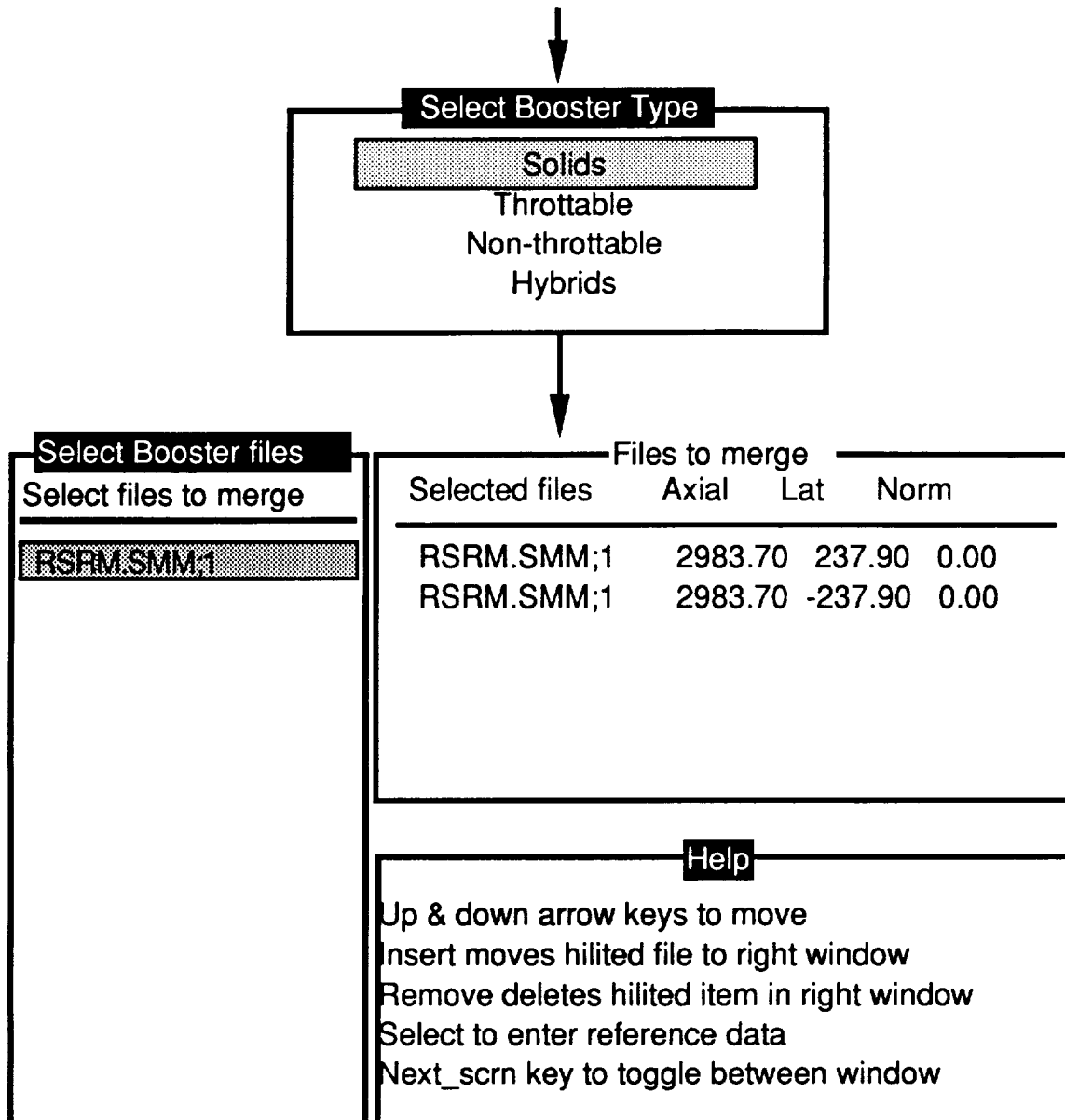


Figure A-40. Merge Module Input Menus (Continued)

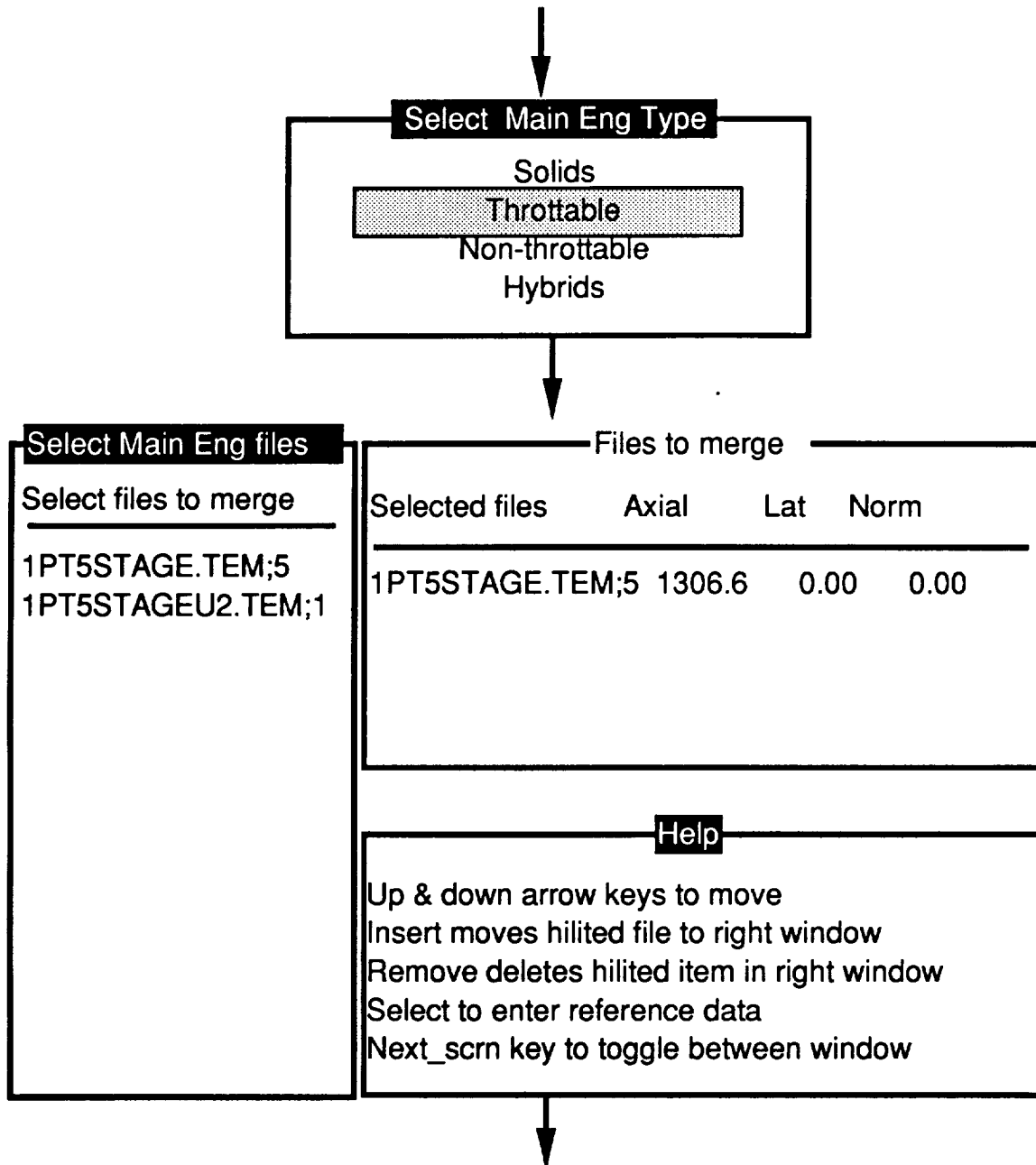


Figure A-40. Merge Module Input Menus (Continued)

Select Inerts to Drop		Inerts to Drop at Thrust Events			
Name	Mass	Name	Mass	Delta Ms	Evnt #
SHROUD NOSE	1944.0	SHROUD NOSE	1944.0	1944.0	4.00
SHROUD	7920.0	SHROUD	7920.0	7920.0	4.00
TRANSITION STR	4358.0	THRUST STRUCTUR	22631.0	14699.0	2.00
FWD STR & AVION	5501.0	STME 6 580K	55621.0	37087.0	2.00
PAYLOAD	49327.0	PROPULSION & SU	23816.0	12416.0	2.00
LOX TANK FWD &	1889.0	BODY STRUCTURE	28474.9	28474.9	2.00
LOX TANK CYL &	10779.0	INV ENVI PROTEC	1676.8	1676.8	2.00
LOX TANK AFT BK	4021.0	SEP AND RECOVER	10369.8	10369.8	2.00
INTERTANK & INS	12493.0	PRIME POWER	90.0	90.0	2.00
LH2 TANK FWD BK	2107.0	ELECT AND INSTR	1182.6	1182.6	2.00
LH2 TANK CYL &	42895.0	TVC SYS	2328.0	2328.0	2.00
LH2 TANK AFT BK	2616.0	RANGE SAFETY	144.4	144.4	2.00
AFT INTERSTAGE/	4365.0	FWD S CASE	26211.7	26211.7	2.00
THRUST STRUCTUR	22631.0	FWD S INSULATIO	4511.7	4511.7	2.00
STME 6 580K	55621.0	FWD S LINER	341.8	341.8	2.00
PROPULSION & SU	23816.0	FWD S INHIBITOR	260.0	260.0	2.00

Figure A-40. Merge Module Input Menus (Concluded)

Once the booster type is selected, the user is given the option to choose the boosters to merge together. All of the available booster motors or engines of the type selected will be displayed in the left hand window. If an old merge file has been selected, some previously selected boosters may appear in the right window. The user should select the boosters that will be used in the left window so that they appear in the right window. Also, if more than one booster module is needed, that module may be selected multiple times. Any modules that are mistakenly selected or any obsolete boosters that appear in the right window may be deleted in the right window. If no boosters are used on a vehicle, all of the entries should be deleted from the right screen and the Return Key pressed to leave the booster section.

If all of the boosters in the right window are correct, the user should then reference the local booster coordinate systems to the global coordinate system. For the case shown, **Figure A-40** the RSRM local location was at the nose of the RSRM. The nose is 2983.7 in. in the axial direction and 237.9 in. in the lateral direction from the global system, and these directions are used as the reference locations. Ten booster modules may be specified for a vehicle. For the example, note that two RSRMs

were specified and placed on opposite sides of the vehicle by using the negative of the lateral reference location.

When the booster file selection has been completed, the main engine section is presented. Again, the user selects what type of engines or motors to display for selection of the main engine modules. This option was chosen to prevent from having to display all of the engines and motors, which was felt to be extraneous because mixing different types of engines and motors was not thought practical for the main engine.

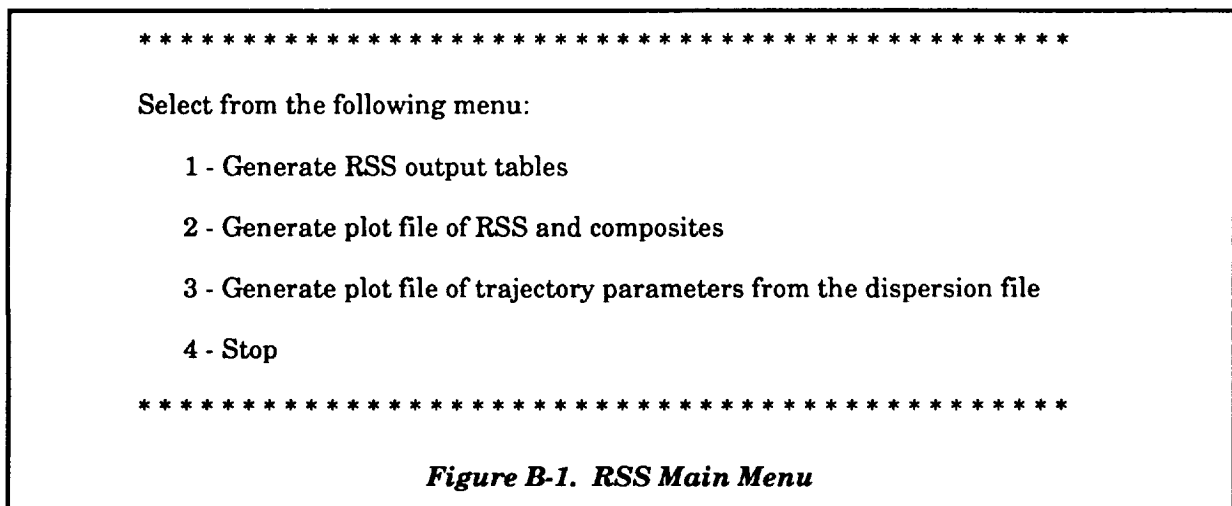
All of the available file types that were selected will be displayed in the left window. To use the main engine data, the user should select the main engines from the left window so that they appear in the right window. Some files may initially appear in the right window if the user has selected an old merge file at the beginning of the sequence. If any files are mistakenly selected or any obsolete files are displayed, they may be deleted in the right window. When all the correct files are in the right window, they should be referenced to the global coordinate system. Therefore, remembering where the reference location of the engine or motor was selected is important. Up to 10 engines or motors may be placed in the right screen. For the screens shown in **Figure A-40**, the 1.5 Stage Common Core was referenced to the tip of the vehicle nose, which is 1306.6 in. from the global coordinate system. Therefore, this value was entered in the axial reference location.

Finally, once all of the inert payload, booster, and main propulsion files have been selected, the user is given the option to select the inert components to drop at thrust events. All of the previously selected files are read to extract the inert components from them. These will be displayed in the left window. The inerts that will be dropped should be selected, placing them in the right window. After all of the inerts are selected, the values should be updated in the right window. Then, the thrust event number, where the inert component should be dropped, and the delta mass at that thrust event should be used. The delta mass was used in case only part of an aggregate was dropped. For the example screens (see **Figure A-40**), the shroud and shroud nose, from the 1PT5STAGE.IPM module, are dropped at the fourth thrust event, the propulsion component structures, from the 1PT5STAGE.TEM module, are only partially dropped at thrust event number two, and the total mass of all the RSRM components, from the RSRM.SMM module, are dropped at the second thrust event. Once all of the inert components to be dropped are specified, the merge module sequence is complete, and the merge module file is calculated.

APPENDIX B. ROOT SUM SQUARE (RSS) PROGRAM USERS MANUAL

The RSS Program is a post-processor program to the MASTRE Program to provide a means for the calculation of dispersion analysis related data. The RSS Program is a separate program and is initiated by the user typing the instruction "RUN RSS_MAIN". The program is user interactive and requests data through a series of menus and prompts.

The first menu displayed is the main menu, which is shown in *Figure B-1*. This menu allows the user to select from one of four selections. If the user inadvertently requests a select less than or equal to zero or greater than four, the message "input out of range, try again" is displayed. The user can then select again. If the user wishes to stop, he can select the fourth option.



Regardless of the option chosen (except for the fourth option), the initial selection of an option will prompt the user to "Input name of dispersion run file." This file is the direct-access file generated by the MASTRE Program (.DSP extension) and contains dispersion run data. After this initial prompt, the dispersion file specified will be used for all options.

If either the first or second option is selected and is the initial selection, the root sum square calculations of the plus and minus dispersion data are performed and stored on the dispersion file. These data, along with the raw dispersion data, can then be either output as tabular data, plot data files, or both.

If the first option is selected, tables in a publishable format are output. The user is first prompted to "Input name of output table file". The file name can contain as many as 80 characters. This file will contain the output tables. *Figure B-2* shows the next display that defines the parameters available.

- | | |
|-------------------------------------|-------------------------------------|
| 1. Axial accelerations (g's) | 13. Inertial azimuth (deg) |
| 2. Altitude (ft) | 14. Geodetic latitude (deg) |
| 3. Radius (ft) | 15. Longitude (deg) |
| 4. Relative velocity (ft/s) | 16. Impact latitude (deg) |
| 5. Inertial velocity (ft/s) | 17. Impact longitude (deg) |
| 6. Dynamic pressure (psf) | 18. Vehicle weight (lb) |
| 7. Rel flight path angle (deg) | 19. Angle of attack (deg) |
| 8. Int flight path angle (deg) | 20. Sideslip angle (deg) |
| 9. Stagnation heating (BTU) | 21. Pitch attitude command (deg) |
| 10. Stagnation heating rate (BTU/s) | 22. Yaw attitude command (deg) |
| 11. Down range (ft) | 23. Liquid propellant consumed (lb) |
| 12. Cross range (ft) | 24. Solid propellant consumed (lb) |

Figure B-2. Trajectory Parameters

The user is then prompted **"Do you wish to output all variable tables? (y/n) [n]."** The user can either type "y", "n", or press the Return Key to indicate the default (shown in brackets). If "y" is input, 24 sets of tables will be produced. If "n" is input, the user is again prompted **"How many variables will be selected?"**. The user specifies a number and is prompted to **"Input the number of the variables from above table"**. The "above table" refers to the parameter list shown in **Figure B-2**. The number of the selected parameters are then input. For each parameter selected, a set of six tables is printed. Each set consists of a positive table and a negative table for the types of dispersion classifications, i.e., propulsion two tables; aerodynamic/environmental; mass properties; guidance, navigation and control; and composites. On each table, the dispersed values of the selected parameter as a function of the dispersion runs are shown along with the rss of the positive dispersions (those having a positive sign), the rss of the negative dispersions (those having a negative sign), the nominal value plus the positive rss, and the nominal value minus the negative rss. No output is sent to the screen, and the user is returned to the main menu after the file is written.

If the second option is selected, the user is prompted to **"Input name of plot file"**. This plot file provides the nominal values, the nominal values plus the positive rss, the nominal values minus the negative rss, the plus composite values, and the negative composite values of selected trajectory

parameters. This plot is output in a format that can be used as an input to the "Cricket Graph" software. The display shown in *Figure B-2* is presented to the user; the user is then prompted **"Do you wish to output all variables? (y/n) [n]"**. The user can either type "y", "n", or press the Return Key to indicate the default (shown in brackets). If "y" is input, all of the parameters are written to the plot file. If "n" is input, the user is again prompted **"How many variables will be selected?"**. The user can choose from 1 to 24 variables. After inputting, the user is prompted to **"Input the number of the variable from above table"**. The "above table" refers to the parameters shown in *Figure B-2*. The formats of the plot file are first a record containing character fields that identify the data followed by records containing the data. No output is sent to the screen, and the user is returned to the main menu after the file is written.

The third option is also a plot file generator but differs from option 2 since dispersion cases can be output on the file for a particular requested parameter. Since this option does not output the rss values, the calculations of the rss values are unnecessary. The user is first prompted to **"Input name of plot file"**. This is followed by the display shown in *Figure B-2*; the user is then prompted **"Select the number of one parameter from above list"**. The user must choose a parameter from the list shown in *Figure B-2*. Following the user selection, a display (see *Figure B-3*) is shown followed by the prompt **"Do you wish to output all dispersion cases? (y/n) [n]"**. The user can either type "y", "n", or press the Return Key to indicate the default (shown in brackets). If "y" is input, all of the dispersion case related data are written to the plot file. If "n" is input, the user is again prompted **"How many dispersion cases will be selected?"**. One to twenty five cases can be specified. The user is again prompted to define the cases to be output on the file by the prompt **"Input the number of the dispersion cases from above table"**. The formats of the plot file are first a record containing character fields that identify the data followed by records containing the data. The records of the output data contain the time from lift-off, the nominal value, the plus composite value, the minus composite value, and the plus and minus dispersion values based on the dispersion cases. This plot is output in a format that can be used as an input to the "Cricket Graph" software. No output is sent to the screen, and the user is returned to the main menu after the file is written.

- | | |
|----------------------------------|------------------------------------|
| 1. STME Vacuum Thrust | 14. Forebody axial force |
| 2. STME Vacuum Isp | 15. Base force |
| 3. STME mixture ratio | 16. Other aerodynamic coefficients |
| 4. STME thrust misalign (pitch) | 17. Wind profiles (head and tail) |
| 5. STME thrust misalign (yaw) | 18. Wind profiles (right and left) |
| 6. ASRM web action time | 19. Atmospheric density |
| 7. ASRM vacuum Isp | 20. Core inert weights |
| 8. ASRM propellant loading | 21. Propulsion mod inert weights |
| 9. ASRM inert weight | 22. Core propellant weight |
| 10. ASRM thrust misalign (pitch) | 23. Center of gravity |
| 11. ASRM thrust misalign (yaw) | 24. Booster pitch steering |
| 12. ASRM thrust imbalance | 25. Booster yaw steering |
| 13. ASRM thrust uncertainty | |

Figure B-3. Dispersion Case Selection Menu